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Ageing inconsistencies and sensitivity analysis for 4WX herring

Incohérence dans la détermination de l'âge et analyse de sensibilité du hareng de 4WX

G.D. Melvin and M.J. Power

Population Ecology Section
Department of Fisheries and Oceans
Biological Station
531 Brandy Cove Road
St. Andrews, N.B.
Canada E5B 2L9

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Abstract

The assessment of 4WX herring has been hampered in recent years by uncertainty in ageing. Recent exchanges of herring otoliths amongst research institutes indicated inconsistencies in reader assigned ages that are both significantly different and biased. This paper looks at the divergence, when it may have occurred and the potential effects on the assessment model. Several approaches were examined to investigate the sensitivity of VPA estimates of fishing mortality and biomass to ageing errors. Age length keys (ALK) were compared and then used to generate a new Catch at Age (CAA) and age disaggregated indices of abundance from 1999 to 2006 for the VPA input. An iterative process to fit a new ALK based on the length distribution of samples from another year's data to investigated to examine the sensitivity of the VPA to the input ALK data. The model did not perform very well and the resulting CAA and VPA outputs were unrealistic. Alternatively, the ALK's from several selected years were applied directly to the length frequency data from 1999-2006 to generate a revised CAA and an index of abundance for these years. Comparison of these VPA results indicated that slight changes in the age structure can have a profound impact on the final output. Estimates of F and biomass from the VPA analyses were found vary by a factor of 2 or 3 based solely on the different growth model inputs. It was concluded that within the range of age differences examined for the sensitivity analysis, accurate ageing is critical in the estimate F and stock biomass. It was also concluded , that regardless of the scenario , the 4WX herring stock remains at a historically low level with little signs of recent improvement. Fishing mortality is still well above $F_{0.1}$ even with a substantial decrease in catches over the past 2 years and the acoustic index of abundance shows only a slight upward trend in 2006.

Résumé

L'évaluation du hareng de 4WX a été ralentie ces dernières années par l'incertitude qui entoure la détermination de l'âge. De récents échanges d'otolites de hareng entre les établissements de recherche ont révélé des incohérences dans les âges assignés par les lecteurs d'otolites, qui sont à la fois largement différents et faussés. Les auteurs du présent document examinent l'écart, le moment où il se serait produit et ses effets possibles sur le modèle d'évaluation. Plusieurs approches ont été étudiées en vue de mesurer la sensibilité aux erreurs de détermination de l'âge des estimations par APV du taux de mortalité par pêche et de la biomasse. Les clés âge-longueur (CAL) ont été comparées, puis utilisées pour produire de nouveaux indices des prises selon l'âge (PSA) et de l'abondance, non regroupés par âge de 1999 à 2006, pour l'APV. Un processus itératif permettant d'intégrer une nouvelle CAL, basée sur la répartition selon la longueur des échantillons à l'aide des données d'une autre année, a servi à examiner la sensibilité de l'APV aux données de la CAL. Le modèle n'a pas été très efficace et les résultats obtenus au plan des PSA et de l'APV étaient peu réalistes. Par ailleurs, la CAL de plusieurs années choisies a été appliquée directement aux données des fréquences de longueur de 1999 à 2006 pour produire un indice de PSA révisé et un indice d'abondance pour ces années. La comparaison des résultats de ces APV a indiqué que de légers changements apportés à la structure d'âge pouvaient avoir des conséquences profondes sur le résultat final. L'estimation de F et de la biomasse d'après les APV variait d'un facteur de 2 ou 3 en fonction uniquement des différents intrants du modèle de croissance. On a conclu que dans l'échelle des différences d'âge examinée pour l'analyse de sensibilité, la détermination exacte de l'âge est cruciale pour l'estimation de F et de la biomasse du stock. On a aussi conclu que, quel que soit le scénario, le stock de hareng de 4WX demeure à un faible niveau historique, sans grands signes d'amélioration récente. La mortalité par pêche est encore bien au-dessus de F0,1 malgré la diminution substantielle des prises au cours des deux dernières années, et l'indice d'abondance obtenu par méthode acoustique affiche une très légère tendance à la hausse en 2006.

Introduction

Assessment of the 4WX herring stock utilizes an aged based assessment model and is therefore dependent upon an accurate and consistent ageing (Power et al, 2006). Over the past couple of years concern has been expressed about the consistency and inter-reader comparability of herring otolith ages (Melvin, 2006). A number of otolith exchanges have been undertaken amongst Canadian and American research institutes to evaluate these inconsistencies and the results were presented at the first herring framework review meeting in October of 2006 (TRAC, 2006). Overall there was poor performance for both the inter and intra-reader tests, although the intra reader differences were not considered to be as problematic. Neither the source of the problem, nor the point in time when it started, could be identified. Given the importance of ages to the current and future assessment methodologies, it was recommended that these issues be resolved before the final framework meeting on data models. In particular, it was requested that historical data be examined to explore the possible timing of the difference or divergence in ageing and to provide an estimate of the time required to correct the problem. The purpose of the study was to investigate: 1) when the ageing inconsistencies began and what if possible might have contributed to the observed difference/divergence; and, 2) to evaluate the implications of these ageing errors by reconstructing the catch-at-age (CAA) using a growth model from years when ageing is assumed to be correct (i.e., sensitivity analysis).

Investigation of Inconsistencies in Ageing

A major stumbling block in the database was the lack of identification of the otolith reader. The ages were input into the database without reader identification, even though reader name fields are available and the information was recorded on the hardcopy datasheet. To ascertain when, and if, observable changes could be identified, we needed to be able to identify what otoliths were read by which reader and when a change in reader occurred. Shortly after the first framework meeting the primary and secondary readers were identified and these data incorporated into the database for the years 1974 to 2005 (Table 1). No ageing was undertaken in 2006 due to the unresolved issues and uncertainty with ageing herring. Table 2 serves to illustrate the number of otoliths read annually by each reader from 1991 to 2005 and identifies years where changes in the otolith readers occurred in the most recent 15 years. In 1995 the responsibility switched from JBS to MJP, while 1998 represented shared responsibility between MJP and FJF. Prior to 1993 it was common practice for the primary and secondary to compare several hundred otoliths annually for quality control. Since 1999 FJF has been the primary reader for herring, reading 98+ % of the 6,000 to 8,500 otoliths read annually.

Identification of when the problem began is even more difficult to discern given the lack of a bench mark and the potential for mixed percent aged during the introduction of a new reader (e.g., 1998). One source of information for evaluating if a change has occurred is the length at age from the biological samples and the continuity of the observations. Major deviations or a sudden discontinuity in the annual size trend of a specific age group could indicate either a real growth change or if this corresponds to a change in readers, a time window may be identified for the ageing problem. Although

possible, it is unlikely that the inconsistencies currently being observed occurred during a period when two readers were available for a significant portion of the age assignments. Comparative aging and consensus on age differences were assumed to act as quality control and to maintain consistency in reading methodology. Consequently, it is probable that any divergence from the standard protocols or practices occurred after 1994 when, for the majority of the subsequent years, a single reader was involved.

Results

The initial stage of the data analysis involved the examination of the historical data for trends or discontinuities in the size at age of herring. Length at age data for the years 1980 to 2005 were examined using box whisker plots to illustrate the median, 25 and 75 percentiles, the 95% confidence interval, and outliers for all gear types within 4X (Appendix 1). The same data for seine and weir samples which were explored independently during the assessment review showed similar trends, but are not illustrated in this document. Examination of box plots of herring lengths (combined gear) by year for each age between 1980 and 2005 indicates several problem areas. For ages 3and 4 there is an obvious discontinuity in size and length distribution that occurs between 1999 and 2000. This change in trend or abrupt shift disappears after age 5 and age 6. However, a different shift seems to begin about age 6 between 1994 and 1995 and persists through until age 10. For the older ages there has also been a progressive increase that in mean length at age since 1999. This is particularly true for age 10 and older. Another observation in the plots is the narrowing of the error bars around the mean, indicating that the size of the fish for a given age is becoming more constant. Break points in the plots approximately correspond to a change in otolith readers. Separating the age data into gear type for 4X shows a consistent pattern and serves to accentuate the zones of discontinuity in some years.

The overall data tend to suggest a gradual decrease in the size of age 2 fish since 2000 which appears to be more extreme in the purse seine collected samples, but is not apparent in the weir samples, and does not carry through to age 3. This may reflect a change in fishery toward harvesting more juvenile fish earlier in the year. Conversely, it would be expected that the weir samples should show a slight increase in length, which they do not, given that more catches from this fishery have been occurring later in the season during the past 6 years. For the older ages (e.g., 5 and older) there also appears to be a contracting of the size distribution associated with a specific age since about 2001. This is reflected in the narrowing of the confidence intervals about the mean and is observed in the entire dataset especially age 6 and older. It would be expected that the 95% confidence interval would broaden given the reduction in number of fish 6 years and older in recent years. There are also fewer outliers than in the past for all ages. Unfortunately, no herring aged 9 or older have been collected in samples since 2003, with very few fish (<5 fish) between 1998-2003. No age 10 fish or older have been observed in herring samples since 1998 in 4X.

In summary, there is an indication that the observed inconsistencies in ageing may have began sometime between 1999 and 2000 for the younger ages and perhaps between 1994 and 1995 for ages 6 and older. Whether or not the differences are the result of an abrupt

change or a gradual drift from standard ageing protocols or a change in growth is unknown. Although the cause of the inconsistencies are unknown, it is evident that there are significant and biased differences between readers. There is also indirect evidence to suggest that the availability of fish length at the time of reading may have a influence on the assigned age. It is believed that multiple readers and consensus will improve the consistency in assigned ages.

Currently two studies are underway to investigate the sources of error and inconsistencies with herring ageing. The first study involves the selection of ~ 100 otoliths for bomb radio carbon assay to determine the actual (within 6 months) age. The second study will utilize a dominant year class (~2000 otoliths) and the ability of readers to track the appropriate cohort as it moves through the fishery. The four institutes involved in the current (both the bomb radio carbon and dominant year tracking) and previous otolith exchanges are, the National Marine Fisheries Service (NMFS), Maine Department of Marine Resources (MDMR), the Department of Fisheries and Oceans St. Andrews (SABS) and the Department of Fisheries and Oceans, Moncton (Gulf).

Sensitivity Analysis

The terms of reference for the 2007 assessment of Nova Scotia / Bay of Fundy herring spawning component include an evaluation of the implications of the aging errors reported in 2006 on the current VPA-based assessment formulation (DFO, 2007). It was assumed that a growth model which utilized the age-length key (ALK) from one or more years where a broad age structure was observed, and the ageing was assumed to be correct, could be used to reconstruct the CAA. Unfortunately, the direct application of an ALK from one year to the length frequency of a different year is known to produce a biased age distribution (year-effect). To overcome this problem we explored the Iterative Age-Length Key (IALK) of Kimura and Chikuni (1987) which is amenable to applying the age-length data sampled from one population to the length frequency data of another (Gavaris and Van Eeckhaute, 1993). The model utilizes the length frequency and ALK of the source year to fit the distribution of the target year to generate a new length at age key (LAK) which is then applied using an iterative process to the numbers at length for the target year.

For 4WX herring it is not a simple task to modify the historical CAA and the age disaggregated acoustic index to reflect variation in the age-length key (ALK) required for a sensitivity analysis. Much of the data for the early years are available in hardcopy only and not easily adjusted to investigate the proposed sensitivities. Adjustment to the VPA input parameters is limited to the most recent portion of the time series. Consequently, based on the analysis above, which suggests that the most significant discontinuity occurred between 1999 and 2000, the sensitivity analysis was restricted to modifications in CAA and the acoustic index of abundance for the 1999 to 2006 period. The CAA from all previous years remained unchanged from the assessment. It should however be noted that the extent of the ageing problem is unknown and will remain so until completion of the on going studies.

CAA Modification

In the current assessment, ALK's are generated monthly for each year and applied to the fishery catch weighted length frequency samples to produce a CAA for each fishery. The monthly CAA data are summed for the total CAA then used as input for the assessment. Constructing a new monthly ALK for each scenario evaluated in the sensitivity analysis would require an enormous amount of time as the current CAA software is not geared for batch processing. Consequently, the analysis was restricted to an annual ALK extracted from biological samples collected in NAFO unit areas 4Xq, 4Xr, and 4Xs, respectively. These are the areas where currently and historically the majority of the fishery occurs. The ALK for each year from 1999 to 2006 was applied to the same year's numbers at length data and a new CAA constructed for the period 1999 to 2006. If no detailed samples were available for a specific size interval in a given year the ages for the length interval from the 1992 ALK were substituted. This occasionally occurred for the small and larger length intervals and varied slightly from year to year. The overall result was that the total number of fish caught in a given year did not change from the current CAA , only the number of fish for a given age within a year changed.

The original ALK's constructed from the monthly age length data were compared with the annual ALK to evaluate if they would produce similar patterns in CAA for 1999 to 2006 (Figure 1). For all years examined, the catch at age constructed from the monthly ALK was very similar in magnitude and trend to the CAA developed from a single annual ALK. The greatest differences appear to occur in the younger years (ages 2-3) where the monthly ALK's tend to reflect more of the size changes associated with the rapidly growing fish than the annual ALK. Beyond age 4 the numbers at age are almost identical. Based on these comparisons, it was concluded that the annual ALK's could be used in conjunction with the annual catch in numbers at length to develop a CAA for evaluation of the ageing error sensitivity.

For the sensitivity analysis we selected the ALK's from 3 years (1992, 1998, and 2002) representing various stock conditions to apply the iterative procedure (IALK) and construct a new CAA. The year 1992 represents a period when stock abundance was around average, 1999 the year the ageing problem may have started, and 2002 a recent year with a relatively broad age distribution. The ALK and length frequency data from each of these years, and the length frequencies from 1999 to 2006 were input into the iterative program to construct a new CAA. Unlike the Expert Opinion (Melvin and Power, 2006) which modified the CAA based on a degrading difference between two otolith readers, this analysis applied the ALK's from 1992, 1998, and 2002 to the catch at length data to create the modified CAA's for evaluating the impact of different growth models on the VPA.

A similar approach was adopted for the age disaggregated acoustic abundance index. The same yearly ALK's and the length frequency data for each survey were then used to apportion the acoustic backscatter into an estimate of biomass by age for each survey. The surveys were then summed for the individual spawning grounds to determine a

spawning stock biomass for each of the main spawning grounds in Southwest Nova Scotia/Bay of Fundy region (Scots Bay and German Bank).

Analysis

The IALK method utilizes an iterative approach based on the length distribution and the ALK of the source year to minimize the error and create a new ALK. This ALK was then applied to the length frequencies from years of interest and the CAA revised. In theory this should overcome year effect. Unfortunately, the method does not always produce realistic results. In cases (years) where the length distribution of the source are very different from the target, the IALK method was unable to correctly discriminate year-class strengths when there was substantial overlap in the length at age amongst age groups. For the herring data this occurred when the 1992 IALK was applied to the annual length frequencies from 1999 to 2006. Examination of the length frequencies for the three growth model years (1992, 1999 and 2002) indicates a marked difference in their distributions (Figure 2). The main feature is the bi and tri-modal distribution of 1999 and 2002 compared to the single peak in 1992. Comparison of the all years (1999-2006) shows similar distinct and different distributions. The result is that the IALK model has difficulty fitting the target years based on the 1992 distribution. In fact, the revised CAA indicated the complete absent of several age groups (e.g., 2000 and 2003 age 4) (Table 3). As such, it was felt that the 1992 model would not provide a realistic estimate of the CAA and it was not included in subsequent VPA analysis. Only the CAA from 1999 and the 2002 data were used with the IALK method and in the following VPA analysis.

As an alternative approach to the IALK method, acknowledging the year effects bias, we directly applied the ALK from 1987, 1992, 1999 and 2002 to the numbers at length from the 1999 to 2006 data to modify the CAA and to examine the effects when a broad age distribution was available. This in essence equates to a period of slow growth (1987), before the ageing problem is believed to have begun (1992), the year in which the problem may have started (1999) and a year (2002) after the problem may have begun. The revised CAA based on this alternative approach is shown Table 4, the acoustic index of abundance overall in Table 5 and the acoustic index of abundance for German Bank in Table 6, all using the same approach. In the most recent VPA formulation only the German Bank acoustic index of abundance was used for tuning due to the poor performance of other spawning areas(Power et al 2006).The revised CAA's and indices of abundance were then used as input to the VPA and the results compared to complete the sensitivity analysis.

VPA Results

The output from the IALK method and applying ALK's from previous years to the CAA and age-disaggregated indices of abundance were used as input parameters for a VPA. Eleven scenarios were investigated:

- IALK method using ALKs from 1999 and 2002 to modify the CAA and overall index of abundance 1999-2006 (two VPA trials)

- ALK from 1987, 1992, 1999 and 2002 to modify the CAA and overall index of abundance for 1999-2006 (four VPA trials).
- ALK from 1987, 1992, 1999 and 2002 to modify the CAA and German Bank index of abundance for 1999-2006 (four VPA trials).
- ALK from 2005 to modify the CAA and overall index of abundance for 2006 (one VPA trials). No ageing was undertaken in 2006.

The VPA formulation was consistent with the 2005 herring assessment and used the following input parameters:

- M= 0.2
- Fully recruited age 6
- PR age 2 = 0.2, age 3 =0.4, age 4= 0.7, age 5= 0.9
- Estimate ages 7, 2007
- Acoustic index for ages 4 to 8
- 2006 and 2007 age 1 set at 1,000,000

VPA Analysis

Output results from the VPA runs which utilized the IALK approach to generate a revised CAA and acoustic index of abundance were discouraging in that they did not provide realistic output. The 1992 data set was excluded even before the VPA analysis and the two other years, 1999 and 2002, produced unrealistic estimates of F and mean square residuals that would result in the formulations being rejected outright (Appendix II). In fact, the 1999 source year completely eliminated several year-classes before they could move through the fishery, estimating biomass at 0. The 2002 source year performed better in that year-classes were not lost, but the error estimates were so high the run would be rejected at an assessment review. Estimated F for the 1999 and 2002 growth model are shown to be extremely high and the biomass for some age groups produced a negative value (Figure 4). . The IALK approach may work well when there are clearly separated length modes; however, for cases such as herring with multiple overlapping length at age modes the model fails. Gavaris and Van Eechaute (1993) made a similar observation. It was thus concluded that the IALK growth models could not fit the data and could not be used for an ageing sensitivity analysis.

The use of an ALK from one year applied to the length frequency of another year is generally considered an invalid approach due to loss of the year effect. However, it may provide some indication of the changes that could be due to ageing error. Given the inability of the IALK growth model to provide realistic modification to the CAA and the indices of abundance, we applied the ALK's from 1987, 1992, 1999, and 2002 to the length frequency distribution of catches from 1999 to 2006 to generate a new CAA and index of abundance. These data were then used as inputs to the same VPA formulations as examined in the IALK sensitivity analysis. Both the overall and German Bank modified indices were explored and applied to 1999 to 2006 data. The mean square residuals and relative errors for all runs were generally within acceptable levels. The VPA output for the 2002 ALK scenario is presented in Appendix III.

The VPA results using inputs derived with the ALK method to generate a CAA and acoustic index of abundance indicates that fishing mortality over the last 5 years remains high ranging from 1.1 to 2.5 in 2006 for the model using the overall index and 0.8 to 2.5 with the German Bank index depending upon the source year (Figure 5 and 6) . Using the 1987 and 1992 ALK's would suggest a decrease in F over the last couple of years while 1999 and 2002 imply an increase even with the reduced catches (TAC). A similar pattern was observed for total biomass and SSB except that the 1992 ALK method showed an increase since 2005. For the other 3 scenarios (1987, 1992 and 1999 ALK's), the biomass continued to decline with the SSB and total biomass estimated at or below 100,000t.

The final analysis involved examination of the VPA analysis used for the 2006 Expert Opinion (Melvin and Power, 2006). In this case the difference between readers was scaled down over the 1999 to 2006 period such that the CAA and the index of abundance shifted from one reader's ages to the other over the 7 years. Details of one of the VPA runs for Reader 1 vs external reader are shown in Appendix IV. Results for the 3 scenarios comparing the three agers with one another indicate that the Fs are substantially below the current assessment and although high, range from 0.4 to 0.8 in 2005. Biomass (both total and SSB) estimates are higher than the ALK method based runs ranging between 80,000 and 220,000 t, and are stable or increasing slightly (Figure 7). Mean square residuals and relative errors are also within acceptable limits.

Summary

It is not possible, from this analysis to determine which, if any, of the above analytical procedures reflect the true state of the 4WX herring stock. Evident from the analysis is that our perception of stock status using an age based assessment model is highly dependent upon correct ageing. Slight changes such as those observed between readers or the use of a different ALK can have a profound impact on the final output. Depending upon the approach taken, estimates of F and biomass from a VPA analysis could be off by a factor of 2 or 3, highlighting the need for consistent within and between reader ageing. Despite this it is also evident, regardless of the scenario, that the 4WX herring stock is at a historically low level and showed little sign of improvement in 2006. Fishing mortality is still well above $F_{0.1}$ even with a substantial decrease in catches over the past 2 years and the acoustic index of abundance shows only a slight upward trend in 2006. The biomass estimates also remain at a very low level. Finally, a proper evaluation of stock status using an age based assessment model can not be undertaken until the ageing problem is resolved.

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Table 1. Historical overview of the number of herring otoliths read and the primary and secondary readers at the St. Andrews Biological Station since 1974.

Year	Number	Primary Reader	Secondary Reader	Year	Number	Primary Reader	Secondary Reader
1974	23,933	JH		1990	11,426	MJP	JBS
1975	18,507	PS		1991	10,826	MJP	JBS
1976	25,355	PS		1992	5,975	JBS	MJP
1977	21,343	PS		1993	4,508	JBS	MJP
1978	14,330	CM		1994	6,233	JBS	MJP
1979	13,470	CM		1995	4,344	MJP	FJF
1980	13,452	CM		1996	6,505	MJP	
1981	10,709	CM		1997	6,223	MJP	
1982	16,338	MJP		1998	7,236	MJP	FJF
1983	13,371	BB	MJP	1999	7,499	FJF	MJP
1984	18,692	BB	MJP	2000	5,267	FJF	MJP
1985	13,101	BB	MJP	2001	7,558	FJF	MJP
1986	12,591	MJP		2002	7,654	FJF	MJP
1987	13,522	MJP		2003	8,681	FJF	MJP
1988	11,738	MJP	JBS	2004	5,817	FJF	MJP
1989	10,606	MJP	JBS	2005	5,825	FJF	MJP

Otolith Readers

Name	Initial	Name	Initial
Billie Burnett	BB	Mike Power	MJP
Jack Fife	FJF	Jeff Sochasky	JBS
Joe Hunt	JH	Peggy Stewart	PS
Collin MacDougall	CM		

Table 2. Summary of the number of herring otoliths read each year from1991 to 2005 by individual reader. No otoliths were read from the 2006 samples.

	Reader			
Year	FJF	JBS	MJP	Total
1991		10,022	804	10,826
1992		5,210	765	5,975
1993	227	3,500	781	4,508
1994	201	6,032		6,233
1995	180	554	3,610	4,344
1996			6,504	6,504
1997			6,223	6,223
1998	3,372		3,864	7,236
1999	7,320		179	7,499
2000	5,141		126	5,267
2001	7,592		6	7,598
2002	7,654			7,654
2003	8,658		23	8,681
2004	5,817			5,817
2005	5,825			5,825
2006				
Total	51,987	25,318	22,885	100,190

Table 3. Revised catch at age (numbers in 000's) for 1999-2006 based on the IALK model using ALKs from 1992, 1999 and 2002. The first series of years represents the original CAA used in previous assessments.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11+	Total
1999	2,694	117,014	233,700	152,777	127,331	54,321	9,338	589	191	69	8	698,033
2000	847	376,448	78,917	110,874	121,344	58,100	24,650	4,292	245	37	14	775,768
2001	51	75,685	330,502	56,217	58,982	30,286	14,483	2,053	263	9	4	568,536
2002	16,965	309,549	100,839	209,395	74,601	27,812	12,739	1,548	59	22	3	753,532
2003	510	488,925	274,124	101,442	86,242	11,816	6,894	381	19	0	0	970,353
2004	3,142	319,530	282,611	124,226	79,305	9,081	3,205	328	35	1	0	821,464
2005	135	71,812	147,691	172,642	26,829	4,193	1,046	47	2	2		424,399
1992 Growth Model												
1999	0	67,771	457,267	12,266	138,922	14,990	6,570	0	0	0	246	698,033
2000	0	29,782	502,751	0	195,818	33,228	14,103	0	0	0	86	775,769
2001	0	985	389,777	77,806	47,571	43,856	8,537	0	0	0	0	568,532
2002	2,330	172,908	257,713	167,313	122,083	25,502	5,677	0	0	0	0	753,526
2003	0	247,646	557,740	0	161,666	0	3,300	0	0	0	0	970,353
2004	0	204,824	440,554	77,155	83,876	14,892	0	0	163	0	0	821,464
2005	0	26,865	227,631	146,203	15,394	8,253	0	54	0	0	0	424,399
2006	0	17,995	236,795	63,552	94,656	0	523	0	0	0	0	413,521
1999 Growth Model												
1999	2,603	118,061	228,941	158,249	127,473	51,324	10,131	1,011	182	42	17	698,033
2000	879	79,556	324,771	91,956	170,117	85,235	21,732	1,403	0	0	121	775,768
2001	0	26,016	111,349	288,594	69,359	56,862	14,581	1,771	0	0	4	568,536
2002	3,570	253,981	88,912	98,300	240,435	55,554	12,314	447	0	16	3	753,532
2003	158	477,466	117,619	191,816	132,593	47,202	2,946	552	0	0	0	970,353
2004	8,009	372,548	30,988	252,186	108,728	48,364	115	526	0	0	0	821,464
2005	1,603	94,260	27,345	176,589	109,183	14,150	1,262	6	0	0	0	424,399
2006	6	53,812	102,509	101,058	131,555	24,226	201	153	0	0	9	413,530
2002 Growth Model												
1999	24,542	115,030	381,299	52,673	91,480	15,394	16,365	614	622	0	13	698,033
2000	0	157,868	367,531	54,838	138,513	24,384	29,620	2,788	61	133	32	775,768
2001	0	23,298	399,580	37,903	66,074	20,719	17,657	3,240	62	0	4	568,536
2002	28,106	258,243	132,695	212,922	78,124	28,343	13,478	1,550	64	4	3	753,532
2003	15,966	468,618	304,499	52,683	111,925	6,886	9,380	346	49	0	0	970,353
2004	68,122	278,850	294,209	96,063	61,470	19,368	3,002	340	41	0	0	821,464
2005	6,537	79,236	179,464	129,456	18,691	9,424	1,508	82	0	0	0	424,399
2006	635	63,410	192,579	82,177	67,186	4,814	2,677	34	11	0	9	413,530

Table 4. Revised catch at age (numbers in 000's) for 1999-2006 using the ALK method based on the 1987, 1992, 1999 and 2002 ALKs. The first series of years represent the original CAA used in previous assessments.

Original Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	2,694	117,014	233,700	152,777	127,331	54,321	9,338	589	191	69	8	698,033
2000	847	376,448	78,917	110,874	121,344	58,100	24,650	4,292	245	37	14	775,768
2001	51	75,685	330,502	56,217	58,982	30,286	14,483	2,053	263	9	4	568,536
2002	16,965	309,549	100,839	209,395	74,601	27,812	12,739	1,548	59	22	3	753,532
2003	510	488,925	274,124	101,442	86,242	11,816	6,894	381	19	-	-	970,353
2004	3,142	319,530	282,611	124,226	79,305	9,081	3,205	328	35	1	-	821,464
2005	135	71,812	147,691	172,642	26,829	4,193	1,046	47	2	2		424,399
2006												
1992 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	753	166,100	272,803	149,405	65,239	29,326	7,595	3,575	2,252	793	193	698,033
2000	1,766	288,532	278,586	132,530	56,545	7,650	7,226	2,708	139	43	23	775,768
2001	300	115,328	326,824	78,638	34,929	5,138	5,157	2,107	106	8	1	568,536
2002	9,865	288,435	262,026	139,742	42,946	4,955	4,094	1,407	52	7	2	753,532
2003	10,399	512,678	305,721	106,236	29,841	2,760	2,068	624	26	1	-	970,353
2004	12,157	379,605	310,286	88,280	26,938	2,469	1,387	323	19	1	-	821,464
2005	2,097	118,983	225,438	63,549	12,431	1,121	639	137	3	0	-	424,399
2006	1,169	122,172	186,918	82,625	18,499	1,283	702	148	5	3	7	413,530
1999 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	969	112,472	234,710	158,298	127,900	52,560	10,346	538	200	23	15	698,033
2000	531	100,315	290,539	118,303	160,011	85,727	19,329	771	190	30	9	775,755
2001	7	32,112	123,950	246,542	98,733	52,914	13,518	648	108	2	2	568,536
2002	3,766	186,013	159,249	120,478	206,074	65,999	11,504	372	72	2	4	753,532
2003	2,133	328,994	275,520	177,274	133,059	47,006	6,134	209	24	-	-	970,353
2004	3,432	282,156	152,475	209,640	124,405	44,578	4,627	130	21	-	-	821,464
2005	560	73,219	69,857	148,610	110,955	19,041	2,115	41	-	-	-	424,399
2006	210	50,061	108,923	103,779	118,178	29,978	2,337	52	3	-	9	413,530
2002 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	16,138	218,919	217,656	149,250	58,600	23,150	12,477	1,578	229	33	2	698,033
2000	6,031	255,518	203,495	159,952	87,088	37,586	22,857	3,011	189	40	-	775,768
2001	1,304	89,710	222,338	164,258	48,697	24,167	15,558	2,395	101	7	1	568,536
2002	28,106	258,243	132,695	212,922	78,124	28,343	13,478	1,550	64	5	2	753,532
2003	34,936	463,576	226,469	153,752	66,331	17,513	7,034	718	25	1	-	970,353
2004	41,554	329,327	198,940	175,073	52,825	18,097	5,216	411	22	1	-	821,464
2005	7,390	98,598	129,595	149,399	29,031	7,745	2,480	158	2	0	-	424,399
2006	4,073	104,347	116,608	127,401	48,101	10,146	2,658	182	5	0	9	413,530
1987 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	4,285	225,721	217,579	163,688	71,260	11,856	2,679	598	208	133	26	698,033
2000	1,581	250,440	206,751	181,588	107,955	20,874	5,156	958	291	139	34	775,768
2001	829	90,748	208,336	185,492	64,251	13,927	3,721	921	223	71	17	568,536
2002	10,117	268,236	128,931	235,715	93,136	13,694	2,990	522	129	49	13	753,532
2003	10,013	479,014	229,777	170,915	70,751	7,910	1,523	379	51	16	3	970,353
2004	11,755	354,462	190,322	196,195	60,393	6,890	1,121	279	32	12	2	821,464
2005	2,227	104,431	118,921	162,065	33,042	3,069	485	148	8	3	0	424,399
2006	1,078	105,612	113,041	139,929	49,242	3,904	574	127	10	4	9	413,530

Table 5. Overall acoustic index of abundance for the combined German Bank, Scots Bay and Trinity Ledge age disaggregated based on the ALK method using the ALK's from 1987, 1992, 1999, and 2002. The first series of years represent the index used in previous assessments.

Original												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	22	11,837	466,939	1,259,696	724,815	173,021	5,775	6,645	941	1,091	2,650,782
2000	179	160,418	170,220	687,340	930,573	496,803	213,924	37,273	2,019	175	1,000	2,699,924
2001	-	87,170	1,499,796	457,975	467,332	279,943	142,956	25,436	2,178	-	-	2,962,785
2002	2,376	81,122	453,103	1,938,353	592,580	217,955	121,346	17,362	799	385	-	3,425,381
2003	-	136,238	1,528,559	926,469	796,381	104,841	59,548	2,081	1	-	-	3,554,118
2004	-	25,675	1,103,423	1,193,644	759,611	117,403	47,312	3,275	2,271	-	-	3,252,614
2005	-	3,705	213,306	966,885	264,704	50,696	15,687	629	-	4		1,515,617
2006												
1992 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	288	201,128	1,058,025	720,368	444,874	106,900	56,559	43,852	15,416	3,374	2,650,782
2000	-	72,122	374,335	1,038,991	632,294	403,307	91,766	44,464	31,575	9,843	1,224	2,699,924
2001	-	42,583	778,964	1,245,851	445,868	284,734	75,804	43,979	33,000	10,586	1,416	2,962,785
2002	31	43,478	417,934	1,711,513	773,533	338,964	70,028	34,820	25,872	8,272	936	3,425,381
2003	18	83,454	1,025,807	1,469,470	639,638	266,347	40,575	16,071	9,342	3,115	281	3,554,118
2004	-	21,480	799,360	1,513,948	560,213	275,995	49,655	17,836	9,646	3,736	745	3,252,614
2005	-	5,357	267,020	769,237	308,829	130,992	21,129	7,758	3,960	1,276	59	1,515,617
2006	-	3,134	199,691	768,574	462,415	186,265	22,965	6,999	2,856	939	45	1,653,883
1999 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	37	9,334	443,430	1,278,134	725,051	178,513	9,595	5,596	-	1,091	2,650,782
2000	-	35,811	131,572	445,848	1,081,136	774,342	217,682	10,651	1,853	547	274	2,699,716
2001	-	20,547	155,586	1,340,411	829,930	471,596	136,961	5,977	1,777	-	-	2,962,785
2002	25	26,243	64,632	544,199	1,927,567	681,075	168,273	9,277	3,887	183	110	3,425,470
2003	5	70,046	225,458	1,512,057	1,262,356	431,084	52,175	936	1	-	-	3,554,118
2004	-	7,324	153,479	1,370,015	1,195,936	463,865	58,595	3,400	-	-	-	3,252,614
2005	-	3,046	40,695	503,126	734,868	207,097	26,110	674	-	-	-	1,515,617
2006	-	1,255	31,061	362,610	928,469	306,754	23,291	442	-	-	-	1,653,883
2002 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	790	243,846	1,129,929	690,818	335,794	208,982	35,977	3,298	623	727	2,650,782
2000	-	110,855	297,174	958,908	680,908	358,288	251,542	39,386	1,922	814	127	2,699,924
2001	-	85,806	887,292	1,183,713	395,542	230,517	153,137	25,764	996	20	-	2,962,785
2002	766	67,882	479,641	1,852,715	648,263	217,557	138,575	19,127	804	51	-	3,425,381
2003	763	137,741	1,133,348	1,440,651	616,110	157,766	62,607	5,110	23	0	-	3,554,118
2004	-	49,734	923,701	1,498,856	498,988	201,946	72,027	6,009	1,288	63	-	3,252,614
2005	-	13,102	313,548	803,697	264,086	87,100	31,826	2,223	34	0	-	1,515,617
2006	-	7,593	231,814	824,781	456,891	105,366	25,917	1,515	7	-	-	1,653,883
1987 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	3,884	187,301	1,305,881	896,808	188,406	50,374	10,431	4,289	1,984	1,424	2,650,782
2000	45	124,069	329,726	1,240,742	796,857	159,994	39,256	6,205	1,776	821	433	2,699,924
2001	-	97,278	758,549	1,366,021	555,583	134,430	39,394	8,375	2,314	696	145	2,962,785
2002	480	71,370	376,409	2,038,485	775,141	125,485	29,652	5,761	1,873	571	153	3,425,381
2003	781	168,219	1,027,959	1,617,045	652,500	70,815	13,353	3,122	232	84	8	3,554,118
2004	-	69,346	781,159	1,696,823	603,787	83,226	13,775	2,790	939	642	126	3,252,614
2005	-	18,901	254,124	893,669	305,641	36,252	5,938	913	141	26	11	1,515,617
2006	-	12,489	193,316	934,593	467,782	39,532	5,417	681	54	15	5	1,653,883

Table 6. German Bank acoustic index of abundance age disaggregated based on the ALK method using the ALK's from 1987, 1992, 1999, and 2002. The first series of years represent the index used in previous assessments.

Original												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	-	9,924	428,280	1,131,660	664,725	163,298	5,561	6,599	934	1,079	2,412,061
2000	179	159,866	146,724	524,346	740,919	360,915	155,853	26,263	1,631	175	996	2,117,866
2001	-	85,238	685,939	185,393	167,059	112,396	61,752	12,400	1,753	-	-	1,311,930
2002	2,366	78,824	334,785	1,370,159	440,402	166,919	90,875	13,560	758	380	-	2,499,028
2003	-	119,130	1,172,040	590,615	494,790	71,925	36,656	1,717	-	-	-	2,486,873
2004	-	22,502	785,706	967,910	571,000	96,778	37,007	2,586	2,271	-	-	2,485,760
2005	-	3,489	182,737	874,175	243,815	46,493	14,539	597	-	-		1,365,846
2006	-	-										
1992 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	177	182,426	958,511	649,033	407,085	100,099	54,011	42,467	14,922	3,332	2,412,061
2000	-	61,593	252,808	710,449	524,889	358,849	93,715	55,356	43,327	14,397	2,483	2,117,866
2001	-	41,431	393,050	516,277	173,762	115,323	32,606	19,382	14,779	4,715	606	1,311,930
2002	31	42,485	322,225	1,206,380	566,323	254,452	53,123	27,267	19,749	6,267	727	2,499,028
2003	-	71,152	777,909	1,022,869	400,136	169,456	26,443	10,736	5,902	2,049	220	2,486,873
2004	-	17,604	592,660	1,174,792	427,703	208,331	39,138	13,939	7,666	3,210	717	2,485,760
2005	-	4,949	231,769	692,330	285,028	120,499	19,330	7,065	3,639	1,182	54	1,365,846
2006	-	2,941	173,119	657,212	405,061	165,358	20,583	6,222	2,490	806	28	1,433,819
1999 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	21	7,344	405,926	1,149,246	663,578	169,882	9,422	5,563	-	1,079	2,412,061
2000	-	35,798	129,569	349,288	825,799	591,332	173,802	9,410	1,844	545	273	2,117,660
2001	-	20,285	128,515	586,842	322,702	188,914	60,482	2,733	1,458	-	-	1,311,930
2002	25	25,902	61,181	410,493	1,351,378	512,001	128,100	6,671	3,077	181	109	2,499,117
2003	-	60,885	163,214	1,163,926	786,040	278,004	34,179	625	-	-	-	2,486,873
2004	-	6,082	108,559	1,039,444	935,219	347,773	45,577	3,107	-	-	-	2,485,760
2005	-	2,856	36,529	435,221	676,773	189,987	23,858	622	-	-	-	1,365,846
2006	-	1,194	28,027	309,739	800,321	273,300	20,865	375	-	-	-	1,433,819
2002 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	555	241,360	1,009,376	633,595	302,934	189,362	32,051	542	784	1,501	2,412,061
2000	-	128,363	246,018	709,362	549,248	262,718	190,117	30,194	424	745	678	2,117,866
2001	-	97,670	454,641	434,339	154,961	94,189	65,389	10,742	-	-	-	1,311,930
2002	228	73,127	383,670	1,286,072	478,806	162,943	101,152	12,630	132	171	97	2,499,028
2003	-	122,577	963,254	875,273	385,048	101,046	36,615	3,060	-	-	-	2,486,873
2004	-	46,965	753,588	1,100,219	375,589	150,173	53,886	3,206	1,032	551	551	2,485,760
2005	-	14,412	294,433	707,299	245,064	75,778	27,136	1,724	-	-	-	1,365,846
2006	-	8,192	217,937	690,480	407,378	87,542	21,400	890	-	-	-	1,433,819
1987 ALK												
Year	1	2	3	4	5	6	7	8	9	10	11	Total
1999	-	3,123	169,309	1,181,724	814,363	176,757	48,457	10,200	4,251	1,967	1,410	2,412,061
2000	-	106,999	209,110	868,210	698,993	169,040	49,699	10,168	3,785	1,231	630	2,117,866
2001	-	85,996	370,554	553,876	220,968	58,006	17,351	3,731	1,028	372	50	1,311,930
2002	477	68,562	290,540	1,437,157	577,532	95,630	22,617	4,488	1,427	483	115	2,499,028
2003	457	135,489	777,646	1,104,998	411,208	45,729	8,821	2,275	179	66	5	2,486,873
2004	-	51,300	576,871	1,322,152	455,841	65,084	10,563	2,292	903	633	122	2,485,760
2005	-	17,164	219,870	807,182	282,006	33,226	5,417	813	133	23	10	1,365,846
2006	-	11,282	168,081	800,188	413,539	35,422	4,715	568	16	8	-	1,433,819

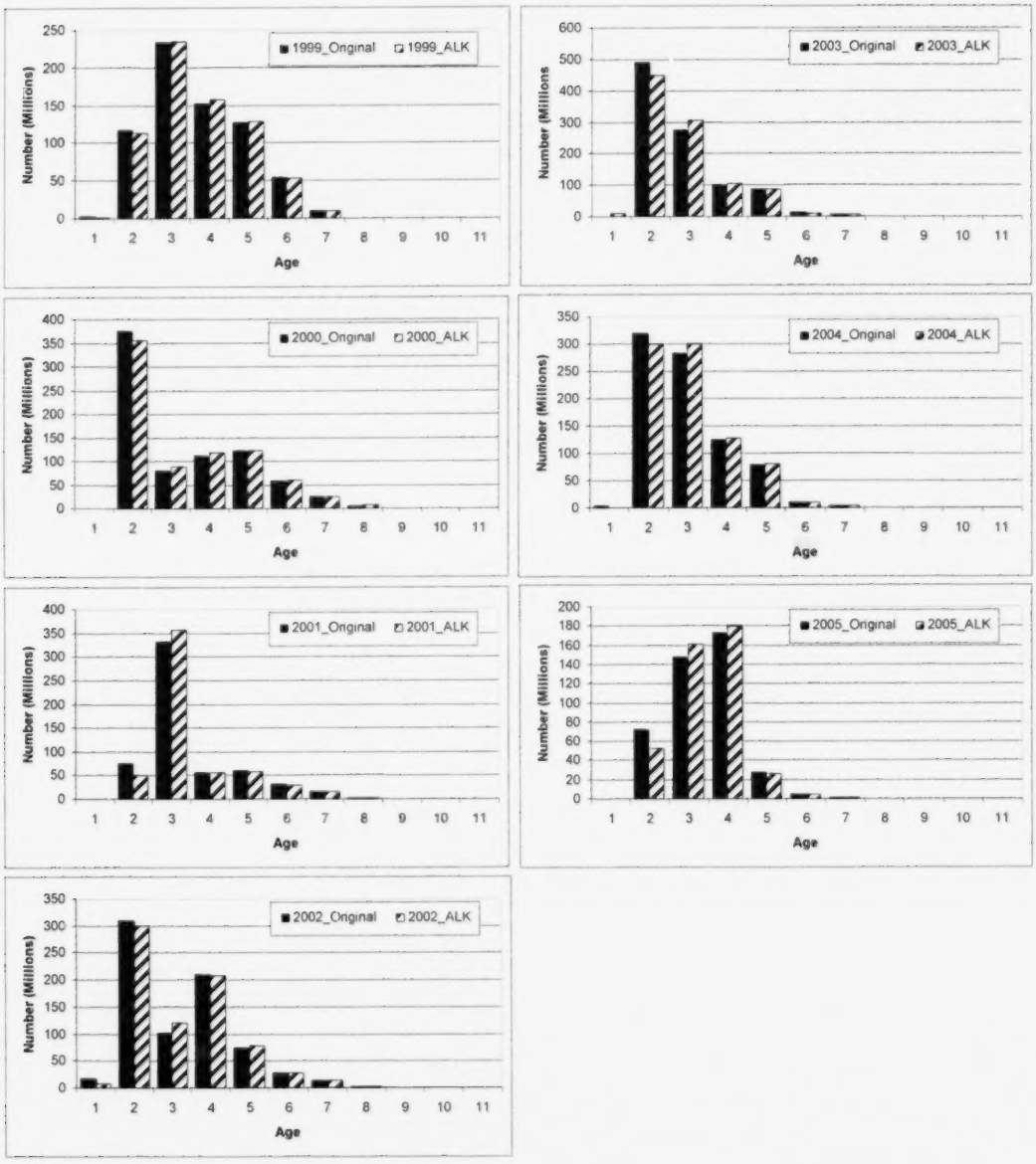


Figure 1. Comparison of the original (previously reported) catch at age in numbers based on monthly ALKs and yearly ALKs from 1999 to 2005 for herring in 4Xqrs.

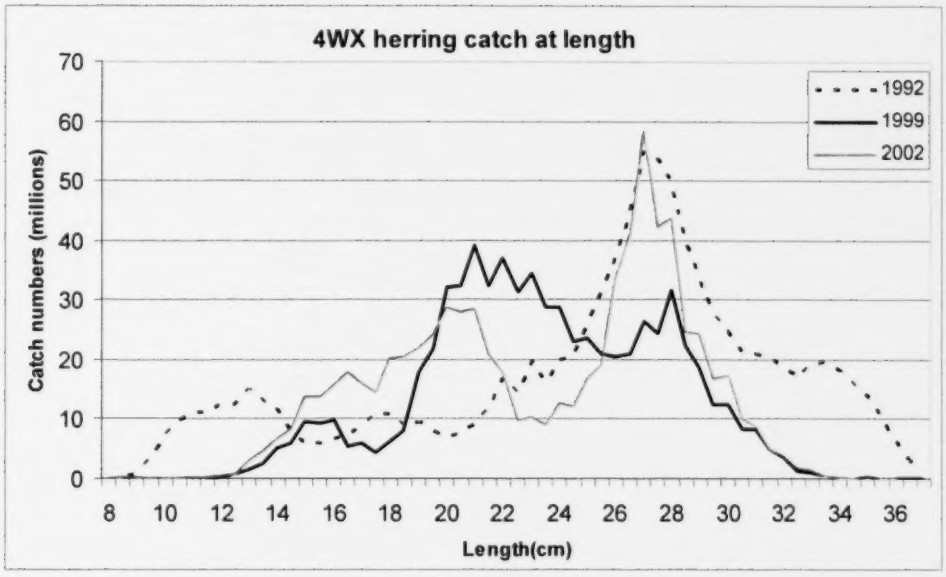


Figure 2. Herring catch at length frequencies for 1992, 1999 and 2002 used as growth model source years for the IALK method.

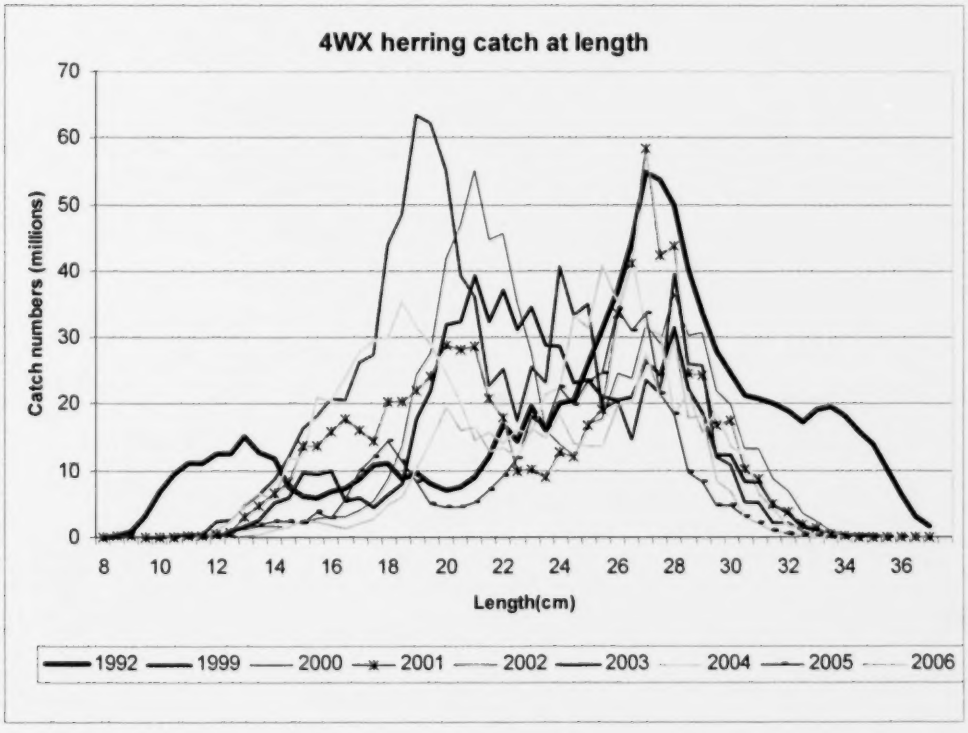


Figure 3. Herring length frequencies for ALK source years (1992, 1999 and 2002) and CAA target year modifications (1999 to 2006).

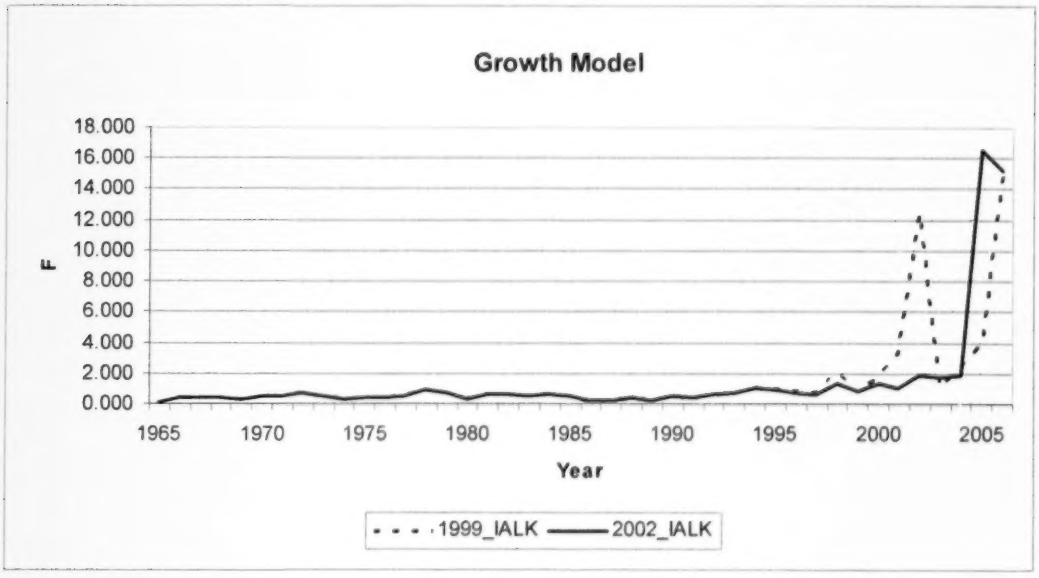


Figure 4. Fishing mortality (F) for the 4X herring stock from a sensitivity analysis using the 1999 and 2002 growth model and the IALK method to modify the CAA.

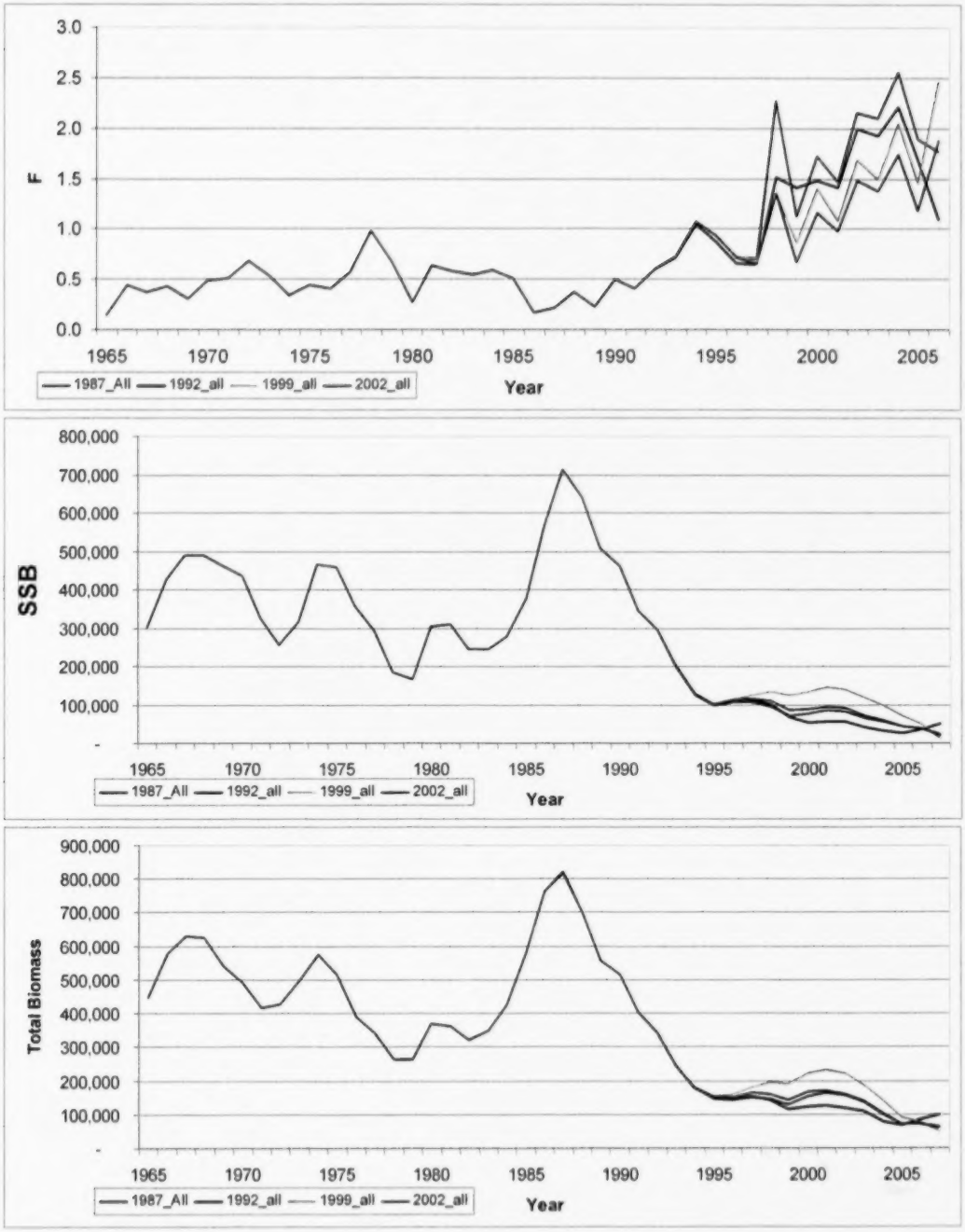


Figure 5. Fishing mortality (F), spawning stock biomass (SSB) and total biomass for the 4X herring stock (ALK method) using the 1987, 1992, 1999 and 2002 ALKs to modify the CAA and overall acoustic index of abundance in the VPA formulation.

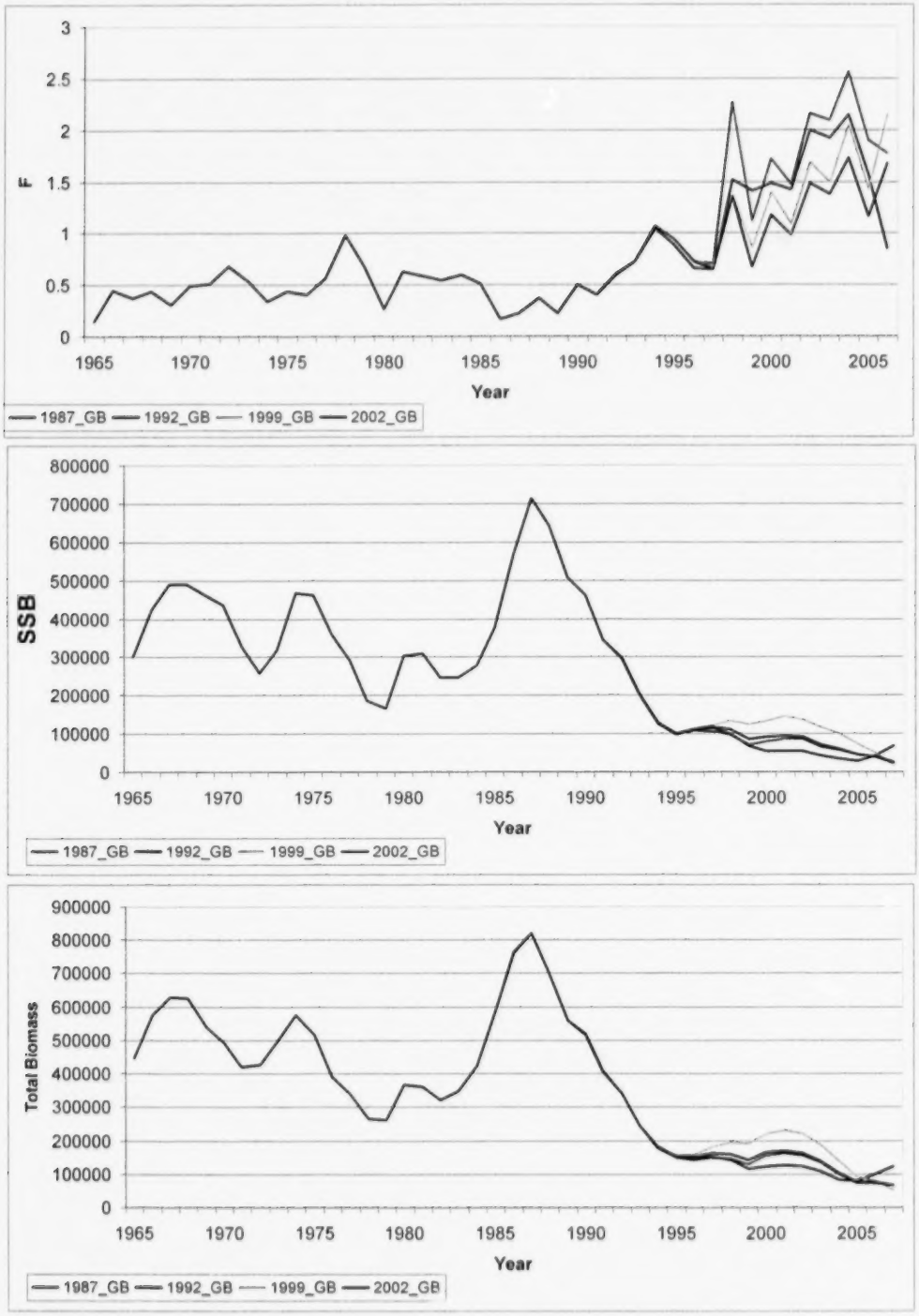


Figure 6. Fishing mortality (F), spawning stock biomass (SSB) and total biomass for the 4X herring stock (ALK method) using the 1987, 1992, 1999 and 2002 ALKs to modify the CAA and German Bank acoustic index of abundance in the VPA formulation.

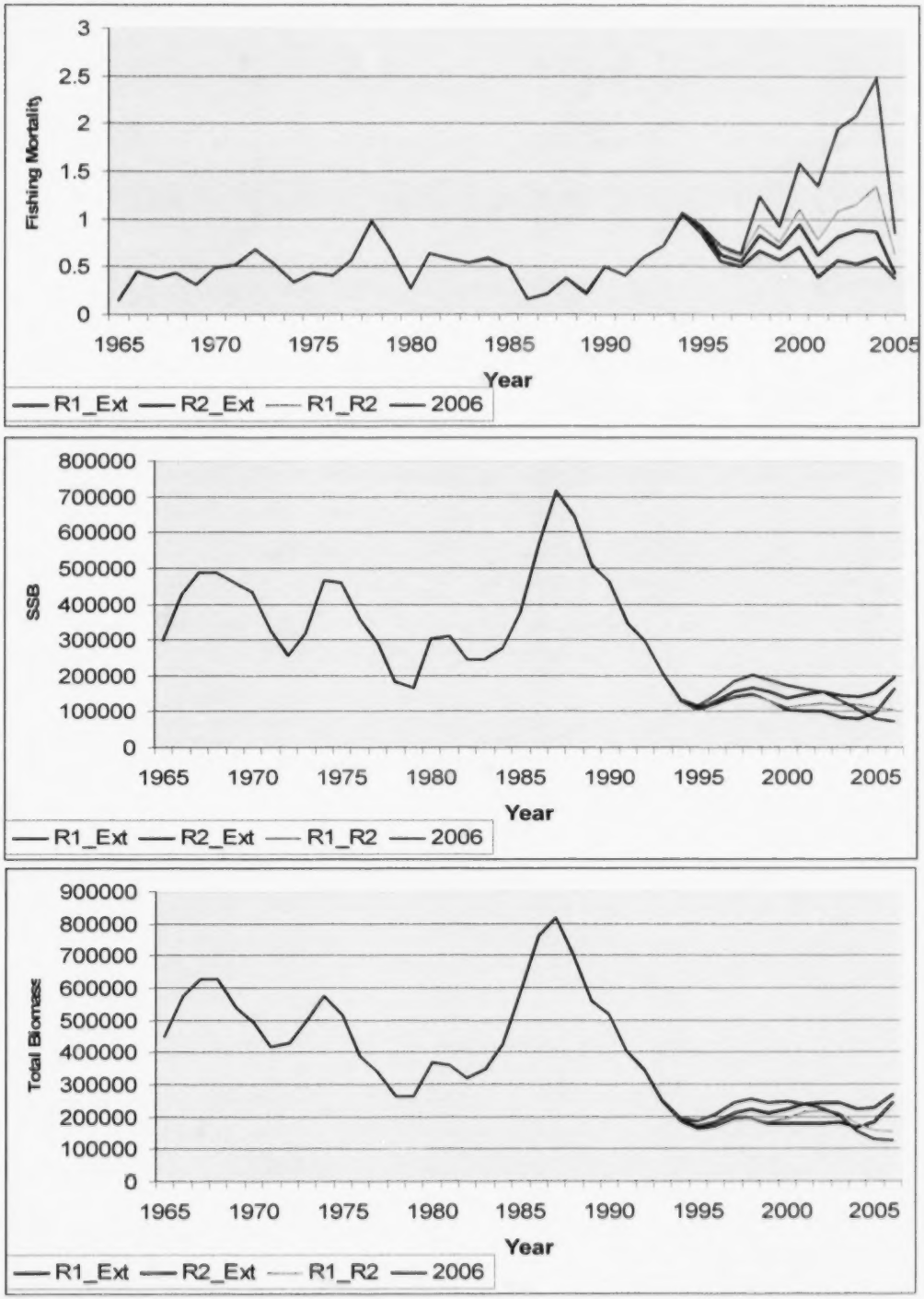
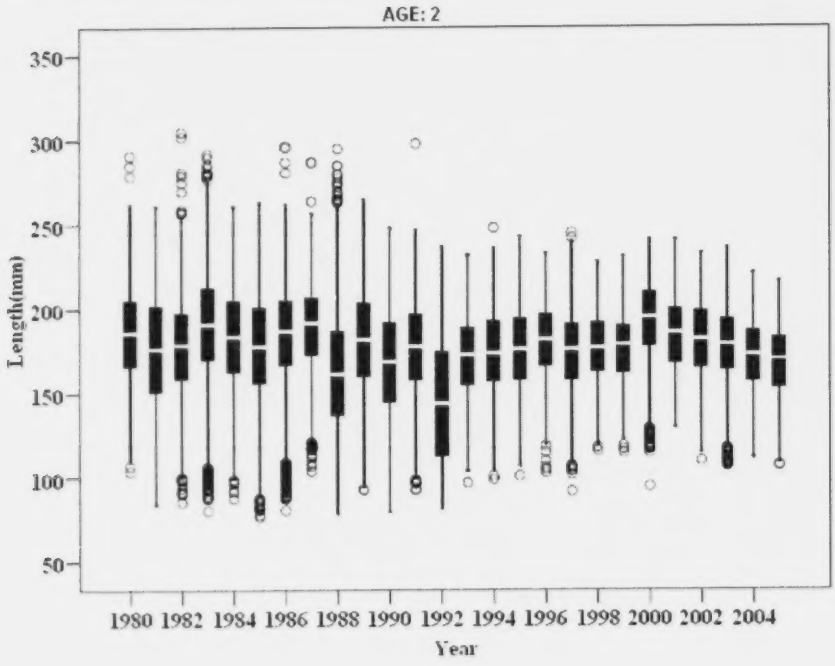
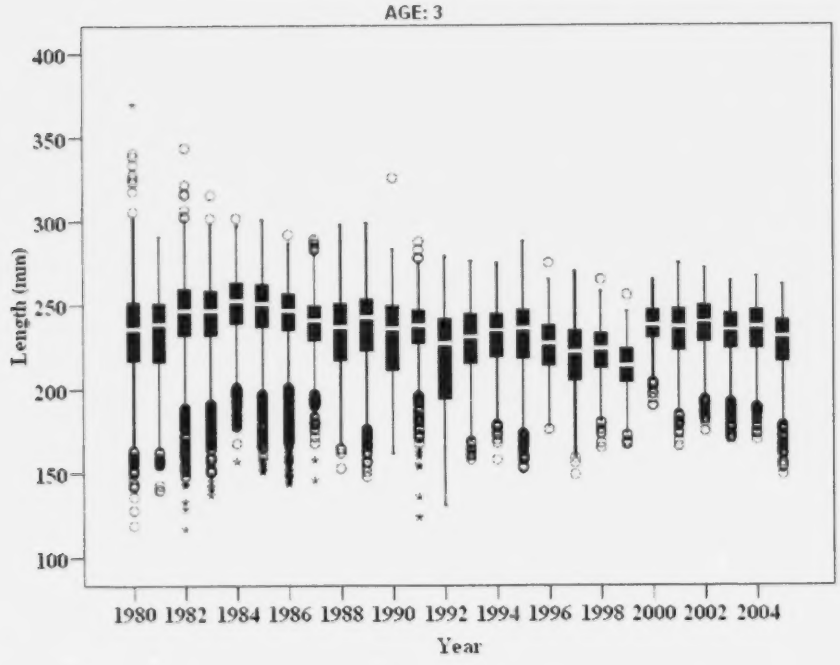
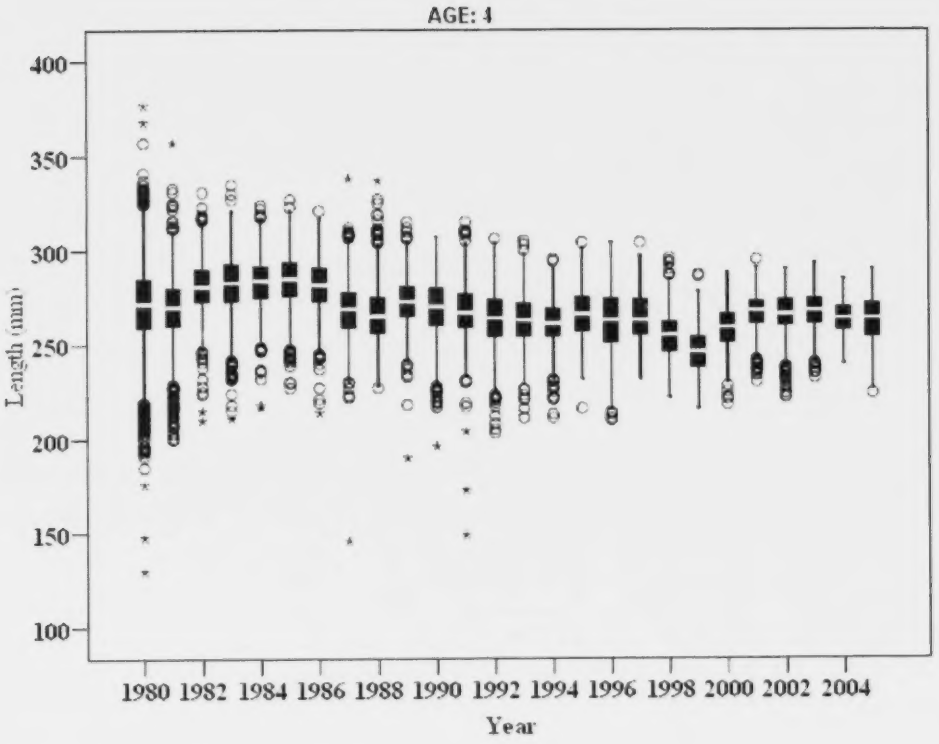


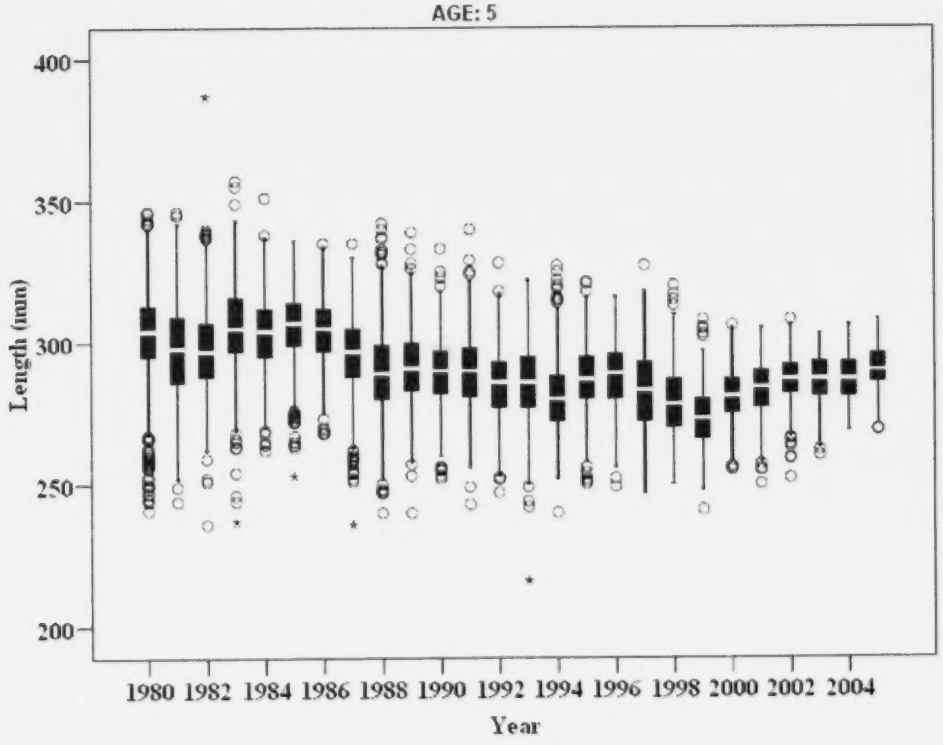
Figure 7. Fishing mortality (F), spawning stock biomass (SSB) and total biomass for the 4X herring stock using the decaying aging from one reader to another between 1999 and 2006 (Melvin and Power, 2006). The 2006 line represents the last analytical assessment.

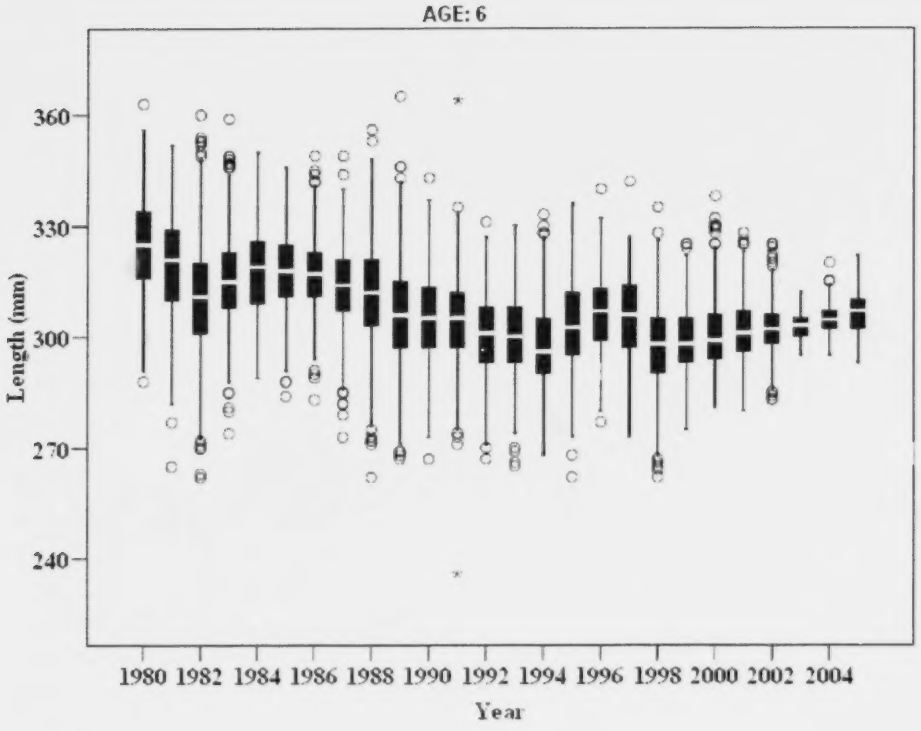
Appendix I. Length at age box plots of herring sampled in 4X for all gear types and months combined for 1980 to 2005 showing the median, 25 and 75 percentiles, the 95% confidence interval, and outliers.

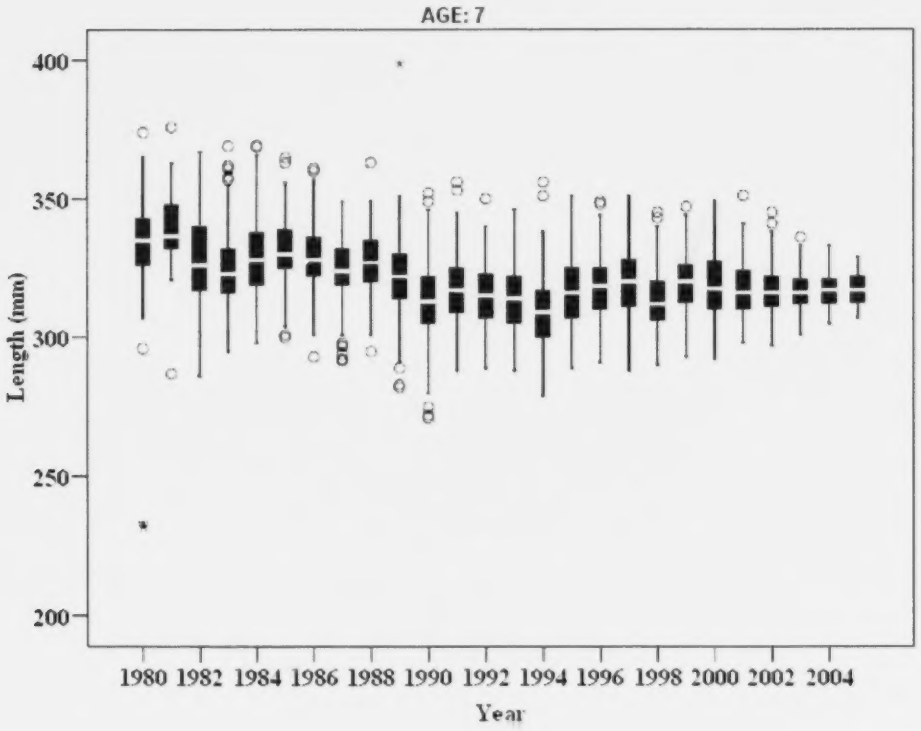


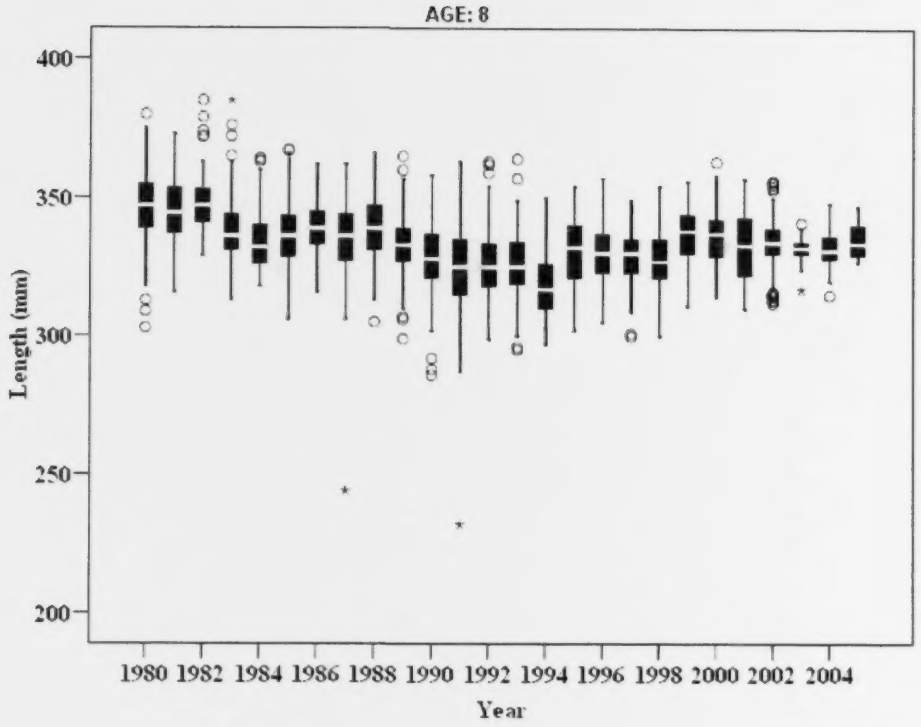


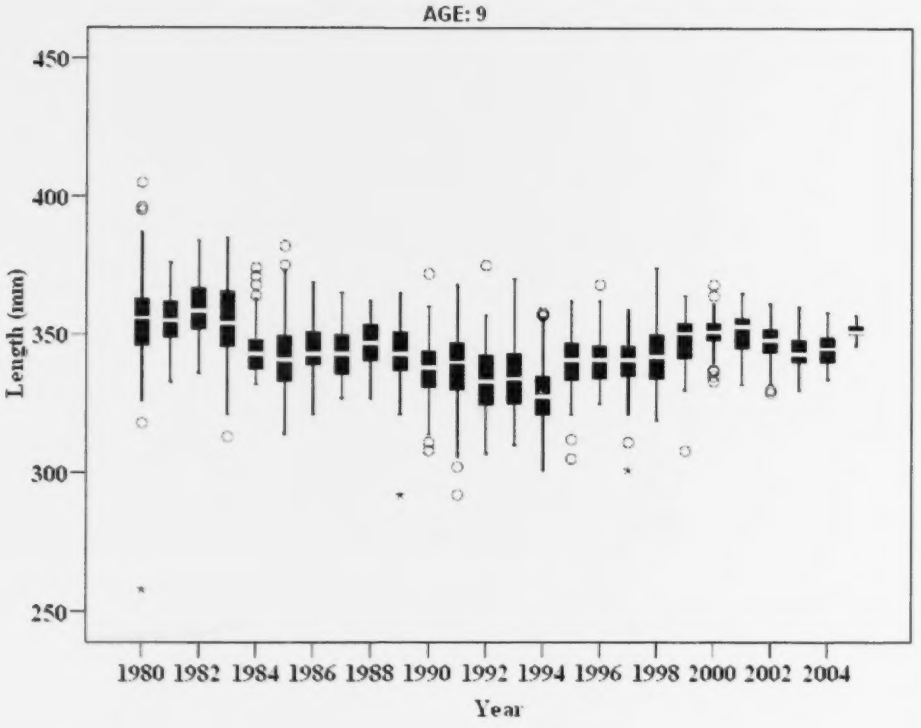

AGE: 4
Length (mm)
400
350
300
250
200
150
100
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year

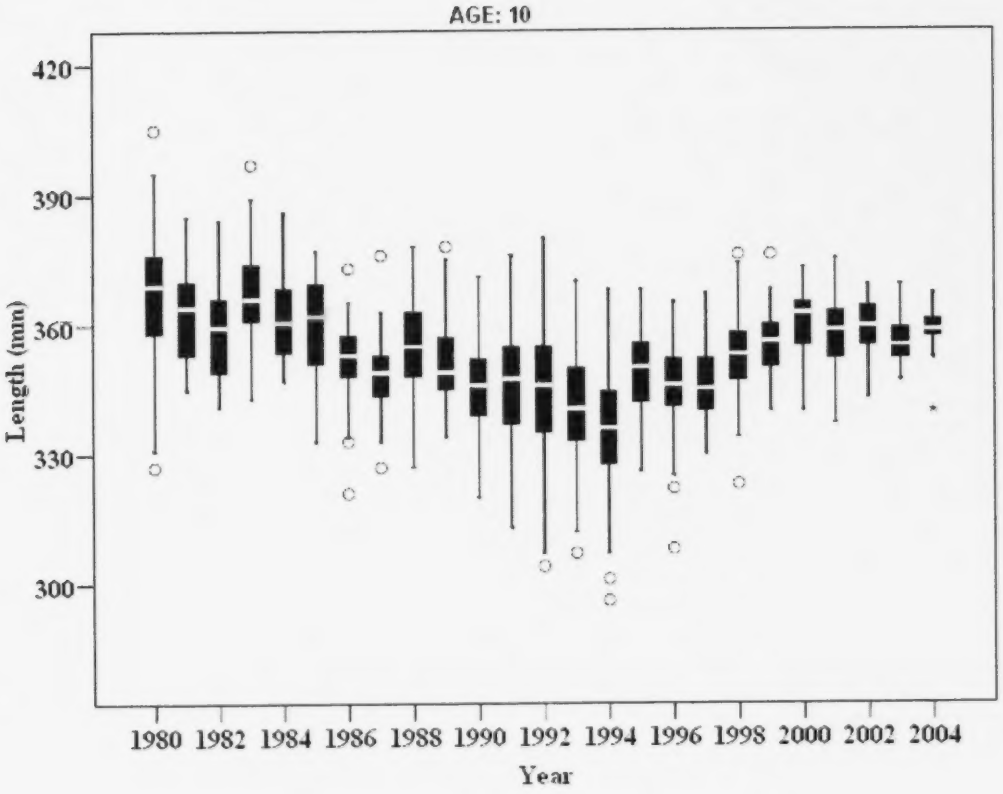

AGE: 5
Length (mm)
400
350
300
250
200
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year


AGE: 6
Length (mm)
360
330
300
270
240
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year


AGE: 7
Length (mm)
400
350
300
250
200
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year


AGE: 8
Length (mm)
400
350
300
250
200
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year


AGE: 9
Length (mm)
450
400
350
300
250
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year


AGE: 10
420
390
360
330
300
Length (mm)
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Year

Appendix II. ADAPT VPA Run using 2002 IALK results to modify the CAA and index of abundance for 1999 to 2006.

Revised Catch at Age Using IALK with 2002 as basis run (numbers in thousands)

	1	2	3	4	5	6	7	8	9	10	11
1965.00	270378	1084719	34835	234383	49925	10592	1693	561	54	37	1
1966.00	154323	914093	448940	73382	321857	45916	13970	7722	1690	215	1
1967.00	722208	613970	153626	266454	110051	159203	57948	4497	409	296	148
1968.00	164703	2389061	224956	83109	290285	73087	90617	31977	15441	5668	1175
1969.00	108875	290329	531812	132319	162439	112631	62506	22595	6345	2693	722
1970.00	699720	576896	76532	286278	201215	120280	111937	41257	21271	7039	2674
1971.00	87570	404224	183896	106630	113566	75593	93620	50022	36618	7536	5695
1972.00	0	649254	71984	148516	77207	75384	49065	48700	26055	13792	11679
1973.00	1018	167454	781061	130851	40128	30334	22046	20249	23871	11630	13386
1974.00	18411	766064	93606	803651	68276	19093	10232	6565	12786	7102	9031
1975.00	3199	317641	239827	124599	514605	66302	12298	4409	4778	3847	6225
1976.00	240	55596	206535	153782	68804	268839	21460	5571	3951	2059	3446
1977.00	1170	153921	31572	218478	119234	51173	177247	13977	3170	1415	3894
1978.00	35381	383611	40887	12906	122108	68410	31088	108975	11082	2425	1676
1979.00	342	183982	250393	54620	5430	23142	18255	11836	41389	4527	2411
1980.00	2339	12503	80518	474091	27930	4373	4692	6560	2985	10641	2739
1981.00	0	103051	50883	102743	451482	32978	2418	2767	1917	538	2149
1982.00	3589	102133	150764	22640	98206	211043	14627	2080	1354	1250	1014
1983.00	5488	191682	150328	244007	24483	60678	89982	10352	1728	642	1324
1984.00	0	88433	243542	224354	146096	22716	21654	28299	9515	2183	9000
1985.00	9022	216740	337591	302782	147670	42404	14075	18178	7997	1201	470
1986.00	63	125300	275903	292792	56937	31599	10770	4320	2942	1356	349
1987.00	2300	82940	126436	527443	242597	45933	19481	7292	3361	3120	650
1988.00	151	148399	113208	195096	434192	236089	42533	21208	4186	3797	2845
1989.00	8	101788	114095	61842	79451	169023	76684	18303	8270	3814	3057
1990.00	0	178532	130176	171560	89922	101066	201901	116788	31466	10572	6848
1991.00	0	96960	179463	183647	88431	41352	50380	80732	45516	18291	13524
1992.00	9	168561	132642	286923	126510	75473	34458	35369	59136	34558	20653
1993.00	166	76405	43766	194198	130713	67708	33820	21481	21893	20684	11175
1994.00	151	103885	142260	53700	118015	72512	36059	14889	8706	10447	15533
1995.00	1831	113457	219777	112245	36784	36402	22127	6474	4217	2957	3566
1996.00	0	37496	37715	256063	54534	16862	9151	3300	1782	1310	1605
1997.00	356	56561	87395	78098	131062	18917	5131	3636	894	620	874
1998.00	137	264901	62322	138751	97065	97464	20679	3856	1730	1288	398
1999.00	24542	115030	381299	52673	91480	15394	16365	614	622	0	13
2000.00	0	157868	367531	54838	138513	24384	29620	2788	61	133	32
2001.00	0	23298	399580	37903	66074	20719	17657	3240	62	0	4
2002.00	28106	258243	132695	212922	78124	28343	13478	1550	64	4	3
2003.00	15966	468618	304499	52683	111925	6886	9380	346	49	0	0
2004.00	68122	278850	294209	96063	61470	19368	3002	340	41	0	0
2005.00	6537	79236	179464	129456	18691	9424	1508	82	0	0	0
2006.00	635	63410	192579	82177	67186	4814	2677	34	11	0	9
2007.00											

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.000499
MEAN SQUARE RESIDUALS 8.001859

Parameter	Est.	Std. Err.	Rel. Err.	Bias	Rel. Bias
N[2007 7]	1.37E3	2.61E3	1.902	2.20E3	1.599
q ID#[3]	4.06E3	4.17E3	1.026	1.94E3	0.478
q ID#[4]	1.79E4	1.84E4	1.026	8.79E3	0.490
q ID#[5]	1.77E4	1.81E4	1.025	8.88E3	0.502
q ID#[6]	4.49E4	4.60E4	1.025	2.25E4	0.502
q ID#[7]	1.39E4	1.42E4	1.024	7.00E3	0.504

VPA using analytical bias adjusted parameters (linear scale)
Population Numbers

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	3503534	3848688	995990	1312007	348049	92556	44658	4104	1354	406	500
1966.00	2737874	2624572	2177169	784001	863223	239988	66231	35035	2855	1060	707
1967.00	6078739	2102325	1329624	1378701	575717	418512	155171	41661	21740	836	1253
1968.00	1286168	4325977	1170158	950142	889042	372334	200109	75150	30056	17430	1311
1969.00	1754254	904620	1415817	755635	702962	467578	239085	82892	32938	10845	9244
1970.00	2304087	1338027	480252	682955	499558	429512	281595	139599	47575	21258	13377
1971.00	7460417	1258574	579796	324285	303152	228973	243661	130382	77266	19947	19640
1972.00	1138007	6028985	667899	309749	169889	146502	119687	115682	61966	30575	20551
1973.00	2336523	931722	4350855	481941	121063	70132	52761	54102	51165	27434	19153
1974.00	1625829	1912063	612115	2859196	277069	63139	30305	23481	26162	20577	15920
1975.00	247148	1314489	880008	416859	1619372	165491	34561	15639	13330	10013	15485
1976.00	721821	199459	790742	505119	229479	864256	76167	17278	8846	6633	11862
1977.00	4140082	590760	113384	461878	275572	126138	466414	43093	9149	3712	10202
1978.00	1346540	3388555	345406	64483	183136	119041	57492	223170	22748	4650	6640
1979.00	449150	1070509	2428553	245946	41184	41880	36645	19392	85497	8737	5577
1980.00	1572601	367424	710839	1762597	152252	28826	13695	13722	5372	33069	5530
1981.00	1669565	1285424	289534	509413	1017308	99518	19663	7007	5380	1742	19616
1982.00	2302841	1366924	959470	191250	324646	429491	51910	13919	3261	2687	15067
1983.00	4078615	1882165	1027015	649787	136178	177676	163382	29368	9523	1459	12505
1984.00	5027338	3334330	1368177	705449	313500	89458	91080	53687	14768	6242	9665
1985.00	1831408	4116036	2650074	900964	376340	126232	52833	55107	18747	3661	3339
1986.00	1059599	1491281	3174332	1865506	466205	175955	65335	30614	28818	8199	4231
1987.00	1397556	867469	1107953	2350109	1263691	330387	115620	43795	21173	20942	8641
1988.00	1401939	1142145	635440	793156	1449885	816339	229120	77124	29291	14309	20825
1989.00	1744644	1147674	801399	418360	474063	797425	456440	149311	44099	20211	22792
1990.00	1184504	1428387	847845	553356	286825	316602	500863	304665	105752	28664	29022
1991.00	583346	969790	1008587	576926	299137	154168	168565	229430	144883	58344	31604
1992.00	822696	477604	706579	664232	307627	165547	89083	92798	115498	77791	45145
1993.00	1684072	673558	239988	459138	287354	138704	68129	42089	44310	41852	51328
1994.00	770563	1378652	482597	157097	202270	118514	53156	25617	15312	16751	47791
1995.00	835010	630747	1035037	267438	80486	60727	32677	11632	7741	4794	29647
1996.00	726637	681994	414297	649760	118586	33044	17394	7184	3763	2584	22361
1997.00	1360697	594920	524534	305189	302812	48390	12023	6089	2935	1491	17807
1998.00	1042082	1113723	436080	350770	179704	130771	22686	5257	1756	1601	14456
1999.00	1641612	853061	673746	300894	163016	60709	21252	730	906	0	11658
2000.00	536662	1321874	594794	212501	198939	52090	35874	3018	62	192	9534
2001.00	********	439382	939986	160891	124718	40515	20878	3477	72	0	7816
2002.00	1542891	********	338711	412339	97657	43258	14703	1693	65	5	6396
2003.00	832501	1237832	********	158548	147843	11483	10318	421	50	0	5235
2004.00	478488	667176	593858	********	82573	22585	3286	349	42	0	4286
2005.00	93111	330391	296866	223808	********	13479	1624	101	0	0	3509
2006.00	1000000	70336	199287	83723	68168	********	2712	34	11	0	2873
2007.00	1000000	818157	2755	373	2	0	ý824	0	0	0	2344

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	0.089	0.370	0.039	0.219	0.172	0.135	0.043	0.163	0.045	0.106	0.002
1966.00	0.064	0.480	0.257	0.109	0.524	0.236	0.264	0.277	1.028	0.252	0.002
1967.00	0.140	0.386	0.136	0.239	0.236	0.538	0.525	0.127	0.021	0.490	0.139
1968.00	0.152	0.917	0.237	0.101	0.443	0.243	0.681	0.625	0.819	0.440	2.943
1969.00	0.071	0.433	0.529	0.214	0.293	0.307	0.338	0.355	0.238	0.318	0.090
1970.00	0.405	0.636	0.193	0.612	0.580	0.367	0.570	0.392	0.669	0.450	0.248
1971.00	0.013	0.434	0.427	0.446	0.527	0.449	0.545	0.544	0.727	0.533	0.383
1972.00	0.000	0.126	0.126	0.739	0.685	0.821	0.594	0.616	0.615	0.678	0.960
1973.00	0.000	0.220	0.220	0.354	0.451	0.639	0.610	0.527	0.711	0.622	1.402
1974.00	0.013	0.576	0.184	0.369	0.315	0.403	0.462	0.366	0.760	0.475	0.958
1975.00	0.014	0.308	0.355	0.397	0.428	0.576	0.493	0.370	0.498	0.545	0.579
1976.00	0.000	0.365	0.338	0.406	0.398	0.417	0.370	0.436	0.668	0.416	0.383
1977.00	0.000	0.337	0.364	0.725	0.639	0.586	0.537	0.439	0.477	0.539	0.540
1978.00	0.029	0.133	0.140	0.248	1.275	0.978	0.887	0.759	0.757	0.838	0.324
1979.00	0.001	0.209	0.121	0.280	0.157	0.918	0.782	1.084	0.750	0.830	0.639
1980.00	0.002	0.038	0.133	0.350	0.225	0.183	0.470	0.736	0.926	0.435	0.775
1981.00	0.000	0.092	0.215	0.251	0.662	0.451	0.145	0.565	0.494	0.413	0.129
1982.00	0.002	0.086	0.190	0.140	0.403	0.767	0.370	0.180	0.604	0.708	0.077
1983.00	0.001	0.119	0.176	0.529	0.220	0.468	0.913	0.487	0.222	0.655	0.124
1984.00	0.000	0.030	0.218	0.428	0.710	0.327	0.302	0.852	1.195	0.483	3.753
1985.00	0.005	0.060	0.151	0.459	0.560	0.459	0.346	0.448	0.627	0.445	0.168
1986.00	0.000	0.097	0.101	0.189	0.144	0.220	0.200	0.169	0.119	0.201	0.095
1987.00	0.002	0.111	0.134	0.283	0.237	0.166	0.205	0.202	0.192	0.179	0.086
1988.00	0.000	0.154	0.218	0.315	0.398	0.381	0.228	0.359	0.171	0.344	0.163
1989.00	0.000	0.103	0.170	0.177	0.204	0.265	0.204	0.145	0.231	0.232	0.160
1990.00	0.000	0.148	0.185	0.415	0.421	0.430	0.581	0.543	0.395	0.517	0.300
1991.00	0.000	0.117	0.218	0.429	0.392	0.348	0.397	0.486	0.422	0.421	0.630
1992.00	0.000	0.488	0.231	0.638	0.597	0.688	0.550	0.539	0.815	0.663	0.691
1993.00	0.000	0.133	0.224	0.620	0.686	0.759	0.778	0.811	0.773	0.773	0.273
1994.00	0.000	0.087	0.390	0.469	1.003	1.088	1.319	0.997	0.961	1.126	0.440
1995.00	0.002	0.220	0.266	0.613	0.690	1.050	1.315	0.928	0.897	1.104	0.142
1996.00	0.000	0.063	0.106	0.563	0.696	0.811	0.850	0.695	0.726	0.803	0.082
1997.00	0.000	0.111	0.202	0.330	0.640	0.558	0.627	1.044	0.406	0.606	0.056
1998.00	0.000	0.303	0.171	0.566	0.885	1.617	3.237	1.558	13.422	1.973	0.031
1999.00	0.017	0.161	0.954	0.214	0.941	0.326	1.752	2.269	1.351	0.717	0.001
2000.00	0.000	0.141	1.107	0.333	1.391	0.714	2.134	3.533	10.491	1.374	0.004
2001.00	0.000	0.060	0.624	0.299	0.859	0.814	2.312	3.774	2.418	1.456	0.001
2002.00	0.020	19.180	0.559	0.826	1.941	1.233	3.354	3.321	10.688	1.825	0.000
2003.00	0.021	0.534	19.344	0.452	1.679	1.051	3.186	2.099	10.485	2.081	0.000
2004.00	0.170	0.610	0.776	18.191	1.613	2.432	3.279	7.237	10.165	2.614	0.000
2005.00	0.081	0.306	1.066	0.989	16.556	1.403	3.667	2.028	5.113	1.650	0.000
2006.00	0.001	3.040	6.080	10.640	13.680	15.200	15.200	15.200	15.200	15.200	0.003

Appendix III: ADAPT VPA Run using 2002 ALK results to modify the CAA and the German Bank acoustic index of abundance from 1999 to 2006.

Annual Catch at Age (000's) using 2002 age length applied to 99-06

	1	2	3	4	5	6	7	8	9	10	11
1965.00	270378	1084719	34835	234383	49925	10592	1693	561	54	37	1
1966.00	154323	914093	448940	73382	321857	45916	13970	7722	1690	215	1
1967.00	722208	613970	153626	266454	110051	159203	57948	4497	409	296	148
1968.00	164703	2389061	224956	83109	290285	73087	90617	31977	15441	5668	1175
1969.00	108875	290329	531812	132319	162439	112631	62506	22595	6345	2693	722
1970.00	699720	576896	76532	286278	201215	120280	111937	41257	21271	7039	2674
1971.00	87570	404224	183896	106630	113566	75593	93620	50022	36618	7536	5695
1972.00	0	649254	71984	148516	77207	75384	49065	48700	26055	13792	11679
1973.00	1018	167454	781061	130851	40128	30334	22046	20249	23871	11630	13386
1974.00	18411	766064	93606	803651	68276	19093	10232	6565	12786	7102	9031
1975.00	3199	317641	239827	124599	514605	66302	12298	4409	4778	3847	6225
1976.00	240	55596	206535	153782	68804	268839	21460	5571	3951	2059	3446
1977.00	1170	153921	31572	218478	119234	51173	177247	13977	3170	1415	3894
1978.00	35381	383611	40887	12906	122108	68410	31088	108975	11082	2425	1676
1979.00	342	183982	250393	54620	5430	23142	18255	11836	41389	4527	2411
1980.00	2339	12503	80518	474091	27930	4373	4692	6560	2985	10641	2739
1981.00	0	103051	50883	102743	451482	32978	2418	2767	1917	538	2149
1982.00	3589	102133	150764	22640	98206	211043	14627	2080	1354	1250	1014
1983.00	5488	191682	150328	244007	24483	60678	89982	10352	1728	642	1324
1984.00	0	88433	243542	224354	146096	22716	21654	28299	9515	2183	9000
1985.00	9022	216740	337591	302782	147670	42404	14075	18178	7997	1201	470
1986.00	63	125300	275903	292792	56937	31599	10770	4320	2942	1356	349
1987.00	2300	82940	126436	527443	242597	45933	19481	7292	3361	3120	650
1988.00	151	148399	113208	195096	434192	236089	42533	21208	4186	3797	2845
1989.00	8	101788	114095	61842	79451	169023	76684	18303	8270	3814	3057
1990.00	0	178532	130176	171560	89922	101066	201901	116788	31466	10572	6848
1991.00	0	96960	179463	183647	88431	41352	50380	80732	45516	18291	13524
1992.00	9	168561	132642	286923	126510	75473	34458	35369	59136	34558	20653
1993.00	166	76405	43766	194198	130713	67708	33820	21481	21893	20684	11175
1994.00	151	103885	142260	53700	118015	72512	36059	14889	8706	10447	15533
1995.00	1831	113457	219777	112245	36784	36402	22127	6474	4217	2957	3566
1996.00	0	37496	37715	256063	54534	16862	9151	3300	1782	1310	1605
1997.00	356	56561	87395	78098	131062	18917	5131	3636	894	620	874
1998.00	137	264901	62322	138751	97065	97464	20679	3856	1730	1288	398
1999.00	16138	218919	217656	149250	58600	23150	12477	1578	229	33	2
2000.00	6031	255518	203495	159952	87088	37586	22857	3011	189	40	0
2001.00	1304	89710	222338	164258	48697	24167	15558	2395	101	7	1
2002.00	28106	258243	132695	212922	78124	28343	13478	1550	64	5	2
2003.00	34936	463576	226469	153752	66331	17513	7034	718	25	1	0
2004.00	41554	329327	198940	175073	52825	18097	5216	411	22	1	0
2005.00	7390	98598	129595	149399	29031	7745	2480	158	2	0	0
2006.00	4073	104347	116608	127401	48101	10146	2658	182	5	0	9
2007.00											

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.000239
MEAN SQUARE RESIDUALS 0.377112

Parameter	Est.	Std. Err.	Rel. Err.	Bias	Rel. Bias
N[2007 7]	1.88E3	8.11E2	0.432	1.60E2	0.085
q ID#[3]	6.51E0	1.44E0	0.222	1.46Eý1	0.022
q ID#[4]	9.56E0	2.12E0	0.222	2.20Eý1	0.023
q ID#[5]	1.16E1	2.57E0	0.222	2.73Eý1	0.024
q ID#[6]	3.51E1	7.79E0	0.222	8.32Eý1	0.024
q ID#[7]	6.26E1	1.39E1	0.222	1.48E0	0.024

VPA using analytical bias adjusted parameters (linear scale)
Population Numbers

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	3503534	3848688	995990	1312007	348049	92556	44658	4104	1354	406	500
1966.00	2737874	2624572	2177169	784001	863223	239988	66231	35035	2855	1060	707
1967.00	6078739	2102325	1329624	1378701	575717	418512	155171	41661	21740	836	1253
1968.00	1286168	4325977	1170158	950142	889042	372334	200109	75150	30056	17430	1311
1969.00	1754254	904620	1415817	755635	702962	467578	239085	82892	32938	10845	9244
1970.00	2304087	1338027	480252	682955	499558	429512	281595	139599	47575	21258	13377
1971.00	7460417	1258574	579796	324285	303152	228973	243661	130382	77266	19947	19640
1972.00	1138007	6028985	667899	309749	169889	146502	119687	115682	61966	30575	20551
1973.00	2336523	931722	4350855	481941	121063	70132	52761	54102	51165	27434	19153
1974.00	1625829	1912063	612115	2859196	277069	63139	30305	23481	26162	20577	15920
1975.00	247148	1314489	880008	416859	1619372	165491	34561	15639	13330	10013	15485
1976.00	721821	199459	790742	505119	229479	864256	76167	17278	8846	6633	11862
1977.00	4140082	590760	113384	461878	275572	126138	466414	43093	9149	3712	10202
1978.00	1346542	3388555	345406	64483	183136	119041	57492	223170	22748	4650	6640
1979.00	449149	1070510	2428553	245946	41184	41880	36645	19392	85497	8737	5577
1980.00	1572601	367423	710840	1762597	152252	28826	13695	13722	5372	33069	5530
1981.00	1669566	1285424	289533	509414	1017308	99518	19663	7007	5380	1742	19616
1982.00	2302859	1366925	959470	191249	324647	429492	51910	13919	3261	2687	15067
1983.00	4078558	1882180	1027016	649787	136178	177676	163382	29368	9523	1459	12505
1984.00	5027358	3334284	1368188	705449	313500	89458	91080	53687	14768	6242	9665
1985.00	1831446	4116052	2650036	900974	376340	126232	52833	55107	18747	3661	3339
1986.00	1059683	1491312	3174345	1865475	466213	175956	65335	30614	28819	8199	4231
1987.00	1397314	867538	1107979	2350120	1263666	330393	115620	43795	21173	20943	8641
1988.00	1402121	1141947	635497	793177	1449894	816318	229125	77124	29291	14309	20825
1989.00	1744792	1147823	801237	418406	474081	797432	456423	149316	44100	20211	22792
1990.00	1185286	1428507	847967	553224	286863	316617	500869	304651	105755	28664	29022
1991.00	580113	970430	1008686	577026	299029	154199	168576	229434	144872	58346	31605
1992.00	828526	474956	707104	664313	307709	165459	89108	92807	115502	77782	45147
1993.00	1670794	678331	237829	459567	287419	138770	68058	42110	44318	41855	51322
1994.00	765808	1367780	486504	155331	202619	118567	53210	25559	15329	16757	47789
1995.00	787026	626854	1026138	270629	79046	61008	32720	11675	7694	4808	29650
1996.00	807744	642709	411113	642482	121182	31874	17619	7218	3798	2546	22374
1997.00	1255453	661324	492372	302582	296885	50499	11077	6271	2963	1519	17787
1998.00	1210331	1027556	490437	324458	177573	125953	24405	4487	1903	1623	14463
1999.00	1366456	990811	603316	345380	141599	58988	17499	1949	317	64	11681
2000.00	808714	1104185	614362	298964	149363	63520	27576	3317	214	57	9586
2001.00	1165706	656672	674333	320540	102331	44893	18617	2602	115	11	7859
2002.00	1411767	953222	456819	352737	116031	40317	15237	1657	68	6	6436
2003.00	1037771	1130477	548514	254904	99755	25889	7981	784	27	1	5269
2004.00	544249	818117	510883	246524	72187	22967	5707	431	23	1	4314
2005.00	465563	408112	375161	240207	47314	12545	2925	174	3	0	3532
2006.00	1000000	374497	245522	191005	64139	12975	3399	232	6	0	2892
2007.00	1000000	815051	212921	96937	43640	10176	1715	449	31	1	2360

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	0.089	0.370	0.039	0.219	0.172	0.135	0.043	0.163	0.045	0.106	0.002
1966.00	0.064	0.480	0.257	0.109	0.524	0.236	0.264	0.277	1.028	0.252	0.002
1967.00	0.140	0.386	0.136	0.239	0.236	0.538	0.525	0.127	0.021	0.490	0.139
1968.00	0.152	0.917	0.237	0.101	0.443	0.243	0.681	0.625	0.819	0.440	2.943
1969.00	0.071	0.433	0.529	0.214	0.293	0.307	0.338	0.355	0.238	0.318	0.090
1970.00	0.405	0.636	0.193	0.612	0.580	0.367	0.570	0.392	0.669	0.450	0.248
1971.00	0.013	0.434	0.427	0.446	0.527	0.449	0.545	0.544	0.727	0.533	0.383
1972.00	0.000	0.126	0.126	0.739	0.685	0.821	0.594	0.616	0.615	0.678	0.960
1973.00	0.000	0.220	0.220	0.354	0.451	0.639	0.610	0.527	0.711	0.622	1.402
1974.00	0.013	0.576	0.184	0.369	0.315	0.403	0.462	0.366	0.760	0.475	0.958
1975.00	0.014	0.308	0.355	0.397	0.428	0.576	0.493	0.370	0.498	0.545	0.579
1976.00	0.000	0.365	0.338	0.406	0.398	0.417	0.370	0.436	0.668	0.416	0.383
1977.00	0.000	0.337	0.364	0.725	0.639	0.586	0.537	0.439	0.477	0.539	0.540
1978.00	0.029	0.133	0.140	0.248	1.275	0.978	0.887	0.759	0.757	0.838	0.324
1979.00	0.001	0.209	0.121	0.280	0.157	0.918	0.782	1.084	0.750	0.830	0.639
1980.00	0.002	0.038	0.133	0.350	0.225	0.183	0.470	0.736	0.926	0.435	0.775
1981.00	0.000	0.092	0.215	0.251	0.662	0.451	0.145	0.565	0.494	0.413	0.129
1982.00	0.002	0.086	0.190	0.140	0.403	0.767	0.370	0.180	0.604	0.708	0.077
1983.00	0.001	0.119	0.176	0.529	0.220	0.468	0.913	0.487	0.222	0.655	0.124
1984.00	0.000	0.030	0.218	0.428	0.710	0.327	0.302	0.852	1.195	0.483	3.753
1985.00	0.005	0.060	0.151	0.459	0.560	0.459	0.346	0.448	0.627	0.445	0.168
1986.00	0.000	0.097	0.101	0.189	0.144	0.220	0.200	0.169	0.119	0.201	0.095
1987.00	0.002	0.111	0.134	0.283	0.237	0.166	0.205	0.202	0.192	0.179	0.086
1988.00	0.000	0.154	0.218	0.315	0.398	0.381	0.228	0.359	0.171	0.344	0.163
1989.00	0.000	0.103	0.170	0.177	0.204	0.265	0.204	0.145	0.231	0.232	0.160
1990.00	0.000	0.148	0.185	0.415	0.421	0.430	0.581	0.543	0.395	0.517	0.300
1991.00	0.000	0.117	0.218	0.429	0.392	0.348	0.397	0.486	0.422	0.421	0.630
1992.00	0.000	0.492	0.231	0.638	0.596	0.688	0.550	0.539	0.815	0.663	0.691
1993.00	0.000	0.132	0.226	0.619	0.685	0.759	0.779	0.811	0.773	0.773	0.273
1994.00	0.000	0.087	0.386	0.476	1.000	1.087	1.317	1.001	0.959	1.125	0.440
1995.00	0.003	0.222	0.268	0.603	0.708	1.042	1.311	0.923	0.906	1.098	0.142
1996.00	0.000	0.066	0.107	0.572	0.675	0.857	0.833	0.691	0.717	0.821	0.082
1997.00	0.000	0.099	0.217	0.333	0.657	0.527	0.704	0.993	0.402	0.591	0.056
1998.00	0.000	0.332	0.151	0.629	0.902	1.774	2.328	2.451	3.188	1.897	0.031
1999.00	0.013	0.278	0.502	0.638	0.602	0.560	1.463	2.011	1.510	0.801	0.000
2000.00	0.008	0.293	0.451	0.872	1.002	1.027	2.161	3.160	2.779	1.436	0.000
2001.00	0.001	0.163	0.448	0.816	0.731	0.881	2.219	3.443	2.700	1.361	0.000
2002.00	0.022	0.353	0.383	1.063	1.300	1.420	2.767	3.909	4.162	1.853	0.000
2003.00	0.038	0.594	0.600	1.062	1.269	1.312	2.720	3.324	3.218	1.683	0.000
2004.00	0.088	0.580	0.555	1.451	1.550	1.861	3.291	4.804	5.509	2.187	0.000
2005.00	0.018	0.308	0.475	1.120	1.094	1.106	2.334	3.170	2.183	1.358	0.000
2006.00	0.005	0.365	0.729	1.276	1.641	1.823	1.823	1.823	1.823	1.823	0.003

Appendix IV: ADAPT VPA run using age reader differences (Reader 1 vs external reader) to modify the CAA and the German Bank acoustic index of abundance for 1999 to 2006.

Catch R1 Ext

	1	2	3	4	5	6	7	8	9	10	11
1965.00	270378	1084719	34835	234383	49925	10592	1693	561	54	37	1
1966.00	154323	914093	448940	73382	321857	45916	13970	7722	1690	215	1
1967.00	722208	613970	153626	266454	110051	159203	57948	4497	409	296	148
1968.00	164703	2389061	224956	83109	290285	73087	90617	31977	15441	5668	1175
1969.00	108875	290329	531812	132319	162439	112631	62506	22595	6345	2693	722
1970.00	699720	576896	76532	286278	201215	120280	111937	41257	21271	7039	2674
1971.00	87570	404224	183896	106630	113566	75593	93620	50022	36618	7536	5695
1972.00	0	649254	71984	148516	77207	75384	49065	48700	26055	13792	11679
1973.00	1018	167454	781061	130851	40128	30334	22046	20249	23871	11630	13386
1974.00	18411	766064	93606	803651	68276	19093	10232	6565	12786	7102	9031
1975.00	3199	317641	239827	124599	514605	66302	12298	4409	4778	3847	6225
1976.00	240	55596	206535	153782	68804	268839	21460	5571	3951	2059	3446
1977.00	1170	153921	31572	218478	119234	51173	177247	13977	3170	1415	3894
1978.00	35381	383611	40887	12906	122108	68410	31088	108975	11082	2425	1676
1979.00	342	183982	250393	54620	5430	23142	18255	11836	41389	4527	2411
1980.00	2339	12503	80518	474091	27930	4373	4692	6560	2985	10641	2739
1981.00	0	103051	50883	102743	451482	32978	2418	2767	1917	538	2149
1982.00	3589	102133	150764	22640	98206	211043	14627	2080	1354	1250	1014
1983.00	5488	191682	150328	244007	24483	60678	89982	10352	1728	642	1324
1984.00	0	88433	243542	224354	146096	22716	21654	28299	9515	2183	9000
1985.00	9022	216740	337591	302782	147670	42404	14075	18178	7997	1201	470
1986.00	63	125300	275903	292792	56937	31599	10770	4320	2942	1356	349
1987.00	2300	82940	126436	527443	242597	45933	19481	7292	3361	3120	650
1988.00	151	148399	113208	195096	434192	236089	42533	21208	4186	3797	2845
1989.00	8	101788	114095	61842	79451	169023	76684	18303	8270	3814	3057
1990.00	0	178532	130176	171560	89922	101066	201901	116788	31466	10572	6848
1991.00	0	96960	179463	183647	88431	41352	50380	80732	45516	18291	13524
1992.00	9	168561	132642	286923	126510	75473	34458	35369	59136	34558	20653
1993.00	166	76405	43766	194198	130713	67708	33820	21481	21893	20684	11175
1994.00	151	103885	142260	53700	118015	72512	36059	14889	8706	10447	15533
1995.00	1831	113457	219777	112245	36784	36402	22127	6474	4217	2957	3566
1996.00	0	37496	37715	256063	54534	16862	9151	3300	1782	1310	1605
1997.00	356	56561	87395	78098	131062	18917	5131	3636	894	620	874
1998.00	137	264901	62322	138751	97065	97464	20679	3856	1730	1288	398
1999.00	4392	118853	211074	143071	123602	57531	20959	3327	3379	166	64
2000.00	11790	358294	69561	95481	106504	59137	44005	10420	8044	604	395
2001.00	3361	103517	261959	76219	48232	30168	28496	7031	6353	535	325
2002.00	33768	298976	89253	153348	80382	37065	35866	8442	8278	545	266
2003.00	37027	508508	237194	125324	67973	29951	37187	9075	9131	341	88
2004.00	32069	363223	221359	137253	61719	29752	34815	8064	8319	204	93
2005.00	7718	105533	115603	115563	64131	23738	18491	3300	3480	68	16
2006.00											

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

ORTHOGONALITY OFFSET..... 0.000261
MEAN SQUARE RESIDUALS 0.299838

Parameter	Est.	Std. Err.	Rel. Err.	Bias	Rel. Bias
N[2006 7]	4.41E4	1.19E4	0.271	1.39E3	0.032
q ID#[1]	7.74Eý1	1.75Eý1	0.227	1.74Eý2	0.022
q ID#[2]	1.96E0	4.39Eý1	0.224	4.36Eý2	0.022
q ID#[3]	2.77E0	6.16Eý1	0.222	6.21Eý2	0.022
q ID#[4]	2.50E0	5.46Eý1	0.219	5.55Eý2	0.022
q ID#[5]	5.25E0	1.14E0	0.218	1.17Eý1	0.022
q ID#[6]	3.33E0	7.16Eý1	0.215	7.46Eý2	0.022

VPA using analytical bias adjusted parameters (linear scale)
Population Numbers

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	3503535	3848668	995990	1312007	348049	92556	44658	4104	1354	406	500
1966.00	2737874	2624572	2177169	784001	863223	239988	66231	35035	2855	1060	707
1967.00	6078739	2102325	1329624	1378701	575717	418512	155171	41661	21740	836	1253
1968.00	1286169	4325978	1170158	950143	889042	372334	200109	75150	30056	17430	1311
1969.00	1754254	904620	1415817	755635	702962	467578	239085	82892	32938	10845	9244
1970.00	2304088	1338028	480253	682955	499558	429512	281595	139599	47575	21258	13377
1971.00	7460434	1258575	579796	324285	303152	228973	243661	130382	77266	19947	19640
1972.00	1138008	6028999	667900	309749	169890	146502	119687	115682	61966	30575	20551
1973.00	2336523	931722	4350866	481941	121064	70133	52761	54102	51165	27435	19153
1974.00	1625831	1912064	612116	2859205	277070	63139	30305	23481	26162	20577	15921
1975.00	247162	1314490	880009	416859	1619380	165492	34562	15639	13330	10013	15485
1976.00	721833	199470	790743	505120	229480	864262	76168	17278	8846	6633	11863
1977.00	4140121	590770	113394	461879	275573	126138	466419	43094	9150	3713	10203
1978.00	1346680	3388588	345415	64491	183137	119042	57492	223174	22748	4650	6640
1979.00	449252	1070623	2428580	245953	41190	41881	36645	19393	85500	8737	5577
1980.00	1572778	367507	710933	1762618	152258	28831	13695	13722	5372	33072	5530
1981.00	1669897	1285569	289602	509489	1017326	99522	19667	7007	5380	1742	19618
1982.00	2303924	1367196	959589	191306	324709	429506	51914	13923	3261	2688	15069
1983.00	4081061	1883051	1027237	649884	136224	177727	163394	29371	9526	1459	12507
1984.00	5030043	3336333	1368902	705631	313579	89495	91121	53697	14771	6244	9667
1985.00	1833301	4118251	2651713	901558	376488	126296	52863	55141	18754	3663	3342
1986.00	1060672	1492831	3176145	1866848	466689	176076	65387	30639	28846	8205	4235
1987.00	1400341	868348	1109222	2351593	1264789	330783	115719	43838	21194	20965	8649
1988.00	1406315	1144424	636159	794195	1451098	817237	229444	77205	29327	14326	20850
1989.00	1749083	1151257	803265	418948	474913	798416	457173	149577	44165	20240	22826
1990.00	1187825	1432021	850778	554883	287307	317297	501674	305265	105969	28718	29073
1991.00	604751	972509	1011561	579326	300383	154561	169132	230089	145373	58521	31691
1992.00	889251	495128	708805	666665	309586	166565	89404	93261	116036	78190	45360
1993.00	1780535	728049	254282	460959	289332	140298	68956	42351	44687	42288	51827
1994.00	1016073	1457629	527198	168791	203751	120122	54450	26287	15524	17057	48553
1995.00	1140072	831754	1099691	303871	90028	61920	33968	12661	8281	4965	30514
1996.00	1027279	931758	578770	702636	148259	40804	18353	8213	4596	3021	23208
1997.00	1346422	841065	729013	439830	345898	72539	18326	6865	3771	2167	18855
1998.00	880054	1102036	637578	518105	289808	165848	42397	10397	2382	2284	15866
1999.00	1675115	720404	664191	465814	299571	150254	49187	16263	5059	425	13355
2000.00	910895	1367501	482810	354471	253012	134714	71512	21533	10323	1152	11076
2001.00	1579011	735130	797772	332635	204466	111912	57445	19501	8332	1388	9117
2002.00	2017076	1289749	508625	418266	203818	124049	64533	21618	9668	1235	7828
2003.00	1796861	1620948	787197	336089	205093	94934	68300	20923	10143	705	6693
2004.00	1861229	1437711	870964	431657	162934	106970	50859	22817	9019	407	5674
2005.00	1000000	1494886	850751	514207	230302	78137	60866	10862	11455	224	4712
2006.00	1000000	811760	1128706	592389	317095	130973	42673	33241	5932	6256	3966

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10	11+
1965.00	0.089	0.370	0.039	0.219	0.172	0.135	0.043	0.163	0.045	0.106	0.002
1966.00	0.064	0.480	0.257	0.109	0.524	0.236	0.264	0.277	1.028	0.252	0.002
1967.00	0.140	0.386	0.136	0.239	0.236	0.538	0.525	0.127	0.021	0.490	0.139
1968.00	0.152	0.917	0.237	0.101	0.443	0.243	0.681	0.625	0.819	0.440	2.943
1969.00	0.071	0.433	0.529	0.214	0.293	0.307	0.338	0.355	0.238	0.318	0.090
1970.00	0.405	0.636	0.193	0.612	0.580	0.367	0.570	0.392	0.669	0.450	0.248
1971.00	0.013	0.434	0.427	0.446	0.527	0.449	0.545	0.544	0.727	0.533	0.383
1972.00	0.000	0.126	0.126	0.739	0.685	0.821	0.594	0.616	0.615	0.678	0.960
1973.00	0.000	0.220	0.220	0.354	0.451	0.639	0.610	0.527	0.711	0.622	1.402
1974.00	0.013	0.576	0.184	0.369	0.315	0.403	0.462	0.366	0.760	0.475	0.958
1975.00	0.014	0.308	0.355	0.397	0.428	0.576	0.493	0.370	0.498	0.545	0.579
1976.00	0.000	0.365	0.338	0.406	0.398	0.417	0.370	0.436	0.668	0.416	0.383
1977.00	0.000	0.337	0.364	0.725	0.639	0.586	0.537	0.439	0.477	0.539	0.540
1978.00	0.029	0.133	0.140	0.248	1.275	0.978	0.887	0.759	0.757	0.838	0.324
1979.00	0.001	0.209	0.121	0.280	0.157	0.918	0.782	1.084	0.750	0.830	0.639
1980.00	0.002	0.038	0.133	0.350	0.225	0.183	0.470	0.736	0.926	0.435	0.776
1981.00	0.000	0.092	0.215	0.250	0.662	0.451	0.145	0.565	0.494	0.413	0.129
1982.00	0.002	0.086	0.190	0.140	0.403	0.766	0.370	0.180	0.604	0.708	0.077
1983.00	0.001	0.119	0.176	0.529	0.220	0.468	0.913	0.487	0.222	0.655	0.124
1984.00	0.000	0.030	0.218	0.428	0.709	0.326	0.302	0.852	1.194	0.482	3.748
1985.00	0.005	0.060	0.151	0.458	0.560	0.458	0.345	0.448	0.627	0.445	0.168
1986.00	0.000	0.097	0.101	0.189	0.144	0.220	0.200	0.169	0.119	0.201	0.095
1987.00	0.002	0.111	0.134	0.283	0.237	0.166	0.205	0.202	0.192	0.179	0.086
1988.00	0.000	0.154	0.218	0.314	0.397	0.381	0.228	0.359	0.171	0.344	0.163
1989.00	0.000	0.102	0.170	0.177	0.203	0.265	0.204	0.145	0.230	0.232	0.159
1990.00	0.000	0.148	0.184	0.414	0.420	0.429	0.579	0.542	0.394	0.515	0.299
1991.00	0.000	0.116	0.217	0.427	0.390	0.347	0.395	0.485	0.420	0.419	0.627
1992.00	0.000	0.466	0.230	0.635	0.591	0.682	0.547	0.536	0.809	0.659	0.687
1993.00	0.000	0.123	0.210	0.616	0.679	0.746	0.764	0.804	0.763	0.761	0.270
1994.00	0.000	0.082	0.351	0.429	0.991	1.063	1.259	0.955	0.940	1.090	0.431
1995.00	0.002	0.163	0.248	0.518	0.591	1.016	1.220	0.813	0.808	1.039	0.138
1996.00	0.000	0.045	0.075	0.509	0.515	0.600	0.783	0.578	0.552	0.641	0.079
1997.00	0.000	0.077	0.142	0.217	0.535	0.337	0.367	0.858	0.301	0.376	0.052
1998.00	0.000	0.306	0.114	0.348	0.457	1.015	0.758	0.520	1.524	0.948	0.028
1999.00	0.003	0.200	0.428	0.410	0.599	0.542	0.626	0.255	1.280	0.557	0.005
2000.00	0.014	0.339	0.173	0.350	0.616	0.652	1.099	0.749	1.806	0.845	0.040
2001.00	0.002	0.168	0.446	0.290	0.300	0.351	0.777	0.502	1.709	0.547	0.040
2002.00	0.019	0.294	0.214	0.513	0.564	0.397	0.926	0.557	2.418	0.657	0.038
2003.00	0.023	0.421	0.401	0.524	0.451	0.424	0.896	0.642	3.017	0.749	0.015
2004.00	0.019	0.325	0.327	0.428	0.535	0.364	1.344	0.489	3.496	0.791	0.018
2005.00	0.009	0.081	0.162	0.283	0.364	0.405	0.405	0.405	0.405	0.405	0.004